Multidisciplinary Oncovascular Surgery is Safe and Effective in the Treatment of Intra-abdominal and Retroperitoneal Sarcomas : A Retrospective Single Centre Cohort Study and a Comprehensive Literature Review

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Multidisciplinary oncovascular surgery is safe and effective in the treatment of intra-abdominal and retroperitoneal sarcomas; a retrospective single center cohort study and a comprehensive review of literature

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What this study adds: The data presented in this study with a large single center cohort and a retrospective review of patients with intra-abdominal and retroperitoneal sarcomas show that oncovascular surgery

enables radical resection required for good local control of retroperitoneal sarcomas and is associated with an acceptable level of complications perioperatively and during follow-up.

Abstract

Objectives: Radical excision of retroperitoneal or intra-abdominal soft tissue sarcomas may necessitate vessel resection and reconstruction. The aim of this study was to assess surgical results of patients with retroperitoneal or intra-abdominal sarcomas involving major blood vessels.

Design: Retrospective single center cohort study and a comprehensive review of literature.

Methods: Patients with retroperitoneal or intra-abdominal sarcomas treated by the oncovascular team in Helsinki University Hospital from 2010 to 2018 were reviewed for vascular and oncological outcomes. A comprehensive review of literature on vascular reconstructions in patients with retroperitoneal sarcoma was performed.

Results: Vascular reconstruction was performed in 17 patients, 11 of whom required arterial reconstructions. 16 of the operations were sarcoma resections; the postoperative diagnosis for one patient was thrombosis instead of the presumed leiomyosarcoma recurrence. Early graft thrombosis occurred in two venous and one arterial reconstructions. Late thrombosis was detected in 3 (18%). The median follow-up time was 27 (range 0-82) months. Of the patients with sarcoma resections 5 (31%) died of sarcoma and further 4 (25%) developed local recurrence or new distant metastases. The comprehensive review of literature identified 37 articles with 110 patients, 89 of whom had IVC reconstruction only. Eight arterial reconstructions were described. Late graft thrombosis occurred in 14%. The follow-up was 0-181 months, during which 57% remained disease free and 7% died of sarcoma.

Conclusions: Vascular reconstructions enable radical resection of retroperitoneal and intra-abdominal sarcomas in patients with advanced disease. The complex surgeries are associated with an acceptable rate of serious perioperative complications and symptomatic thrombosis of the repaired vessel is rare. However, further studies are needed to assess the performance of the vascular reconstructions in the long term.

Key words: oncovascular surgery, vascular reconstruction, sarcoma, retroperitoneum

Introduction

Radical excision is the most effective treatment in reducing local recurrence and improving overall survival in soft tissue sarcomas. [1-4] Intra-abdominal and retroperitoneal sarcomas are, however, often discovered late due to the relatively abundant potential space for expansion. Due to their location these tumors tend to infiltrate early into surrounding major blood vessels. Patients with tumors invading or intimately surrounding major blood vessels at time of diagnosis have traditionally been regarded inoperable.

Advancements in oncological treatment and operative techniques have resulted in the possibility of radical treatment being offered to sarcoma patients with increasingly advanced disease in cases which previously could not be operated on. When no clear tissue margin between the tumor and the associated blood vessels is evident on imaging, and the tumor cannot be dissected off the vessels, the vessels are resected, and major vessels are reconstructed. Provided clear margins are achieved with the resection, the need for vascular resection is not associated with worse oncological prognosis.[5]

Most reports of venous and arterial reconstructions in patients with intra-abdominal or retroperitoneal sarcomas are case reports or small series from single institutes. Thus, the long-term patency rates of various reconstruction materials and the complication rates associated with the vascular reconstructions have yet to be well established. We present here our experience of vascular reconstructions in patients with retroperitoneal sarcomas with or without intra-abdominal involvement (hereafter referred to as retroperitoneal sarcoma) in Helsinki University Hospital between 2010 and 2018. We also assess the safety and long-term results of vascular reconstructions in patients with retroperitoneal sarcoma through a comprehensive review of the literature.

Materials and Methods

Case series

All new patients diagnosed with soft-tissue sarcoma in University of Helsinki have been treated by a multidisciplinary team since 1987. Diagnostic procedures and treatment are planned at weekly meetings including surgeons, oncologists, radiologists and pathologists.

A multidisciplinary oncovascular team was established in Helsinki University Hospital in 2015, after we identified a substantial increase in unplanned vascular consultations prior to and even during tumor surgery. The team meets every second week to handle different tumors invading or growing in the vicinity of large vessels. The oncovascular team includes dedicated experienced consultants from different specialties including vascular, gastrointestinal, endocrinological, urology and cardiothoracic surgery and

radiology. The team works in close collaboration with other previously established oncological multidisciplinary teams, regarding this report most importantly the sarcoma group. The oncovascular team has a national consultation role.

We performed a retrospective review of records of all patients operated for retroperitoneal sarcoma by members of the oncovascular team of Helsinki University Hospital between January 2010 and February 2018, the years surrounding the formal conception of the team. Inguinal sarcomas were excluded. Twenty-three patients were operated on. Of these, seventeen patients required one or more vascular reconstructions and were included in this study. For the other six, the tumor was resected off the vessels without the need for concomitant vessel reconstruction. All operations were laparotomies and no simultaneous thoracotomies were performed. Temporary warm blood visceral perfusion, using the axillary artery as an inflow route, was used when long occlusion times were anticipated. [6]

Literature review

We set to assess the patency and complication rates of vascular reconstructions in patients with intra-abdominal or retroperitoneal sarcomas through a comprehensive review of literature following PRISMA guidelines.[7] We performed a systematic literature search on 27.1.2020 on the databases World of Science, MEDLINE and SCOPUS with terms shown in *Supplement 1*. Articles including patients with vascular reconstructions during the resection of retroperitoneal sarcomas were identified. (Flow chart in *Supplement* 2) Articles with sufficient data to assess individual vessel reconstructions were included in further analysis (*Table 4*). Case series where individual patients or reconstructions were unidentifiable are summarized in *Supplement 3*.[5, 8-16]

Statistical analysis

Results are given in median (range) unless stated otherwise. Estimates of survival or times to recurrence were calculated with Kaplan-Meier analysis using IBM SPSS Statistics 25 and reported as median or proportion event-free at three years.

Results

Case series

Seventeen sarcoma patients were included. Thirteen were female. For ten of the patients, the surgery involving vascular reconstruction was the first operation for the sarcoma. The median age at operation was 59 (26-70) years.

Ten patients had leiomyosarcoma, 5 had liposarcoma, 1 had undifferentiated pleomorphic sarcoma and 1 had an epithelioid angiosarcoma. One patient with a 2-year earlier resection of a leiomyosarcoma was operated for a suspected intravascular recurrence in the inferior vena cava (IVC), but only thrombosis and scar tissue was found in the histological examination. Preoperative biopsy with a sheathed needle was performed to confirm histological diagnosis in seven of the ten patients undergoing primary operation. The biopsy was performed through a posterior approach to avoid contaminating the peritoneal cavity. The three patients who were not biopsied had preoperative imaging strongly suggestive of leiomyosarcoma.

A wide resection margin, defined as a tumor free margin of at least 2.5 cm, or marginal margin was achieved in 14 (88%) of the patients with two resections being intralesional on histology. Vessel walls were infiltrated by, or the origin of, the tumor in seven patients. Eleven patients had one or more visceral organs resected to improve resection margins. Altogether 40 vascular reconstructions were performed. One or more arterial reconstructions were performed in 11 (65%) of the operations, combined with a venous reconstruction in 8 (47%). IVC was the only vessel reconstructed in 2 (14%) and altogether 9 (64%) IVC reconstructions were performed. Polyethylene was the preferred material for arterial interpositions and was used in 15/19 vessels. Of the 20 venous reconstructions 3 were with patch and 17 venous interpositions were performed. Further details of the patients and operations are listed in *Tables 1* and *2*.

The median operation duration was 7.02 (3.62-13.16) hours. Median blood loss was 3700 (550-13 300) ml which was substituted with 5 (0-22) units of red blood cells and nadir Hb was 89 (72-114) g/l. All but one patient were treated postoperatively at the intensive care unit for 3 (0-9) days and 6 developed transient acute kidney injury (AKI). One patient required temporary dialysis. (*Table 3*) All patients received low molecular weight heparin twice daily adjusted according to the weight as soon as the bleeding risk was considered acceptable. Patients with venous reconstructions had mechanical lower leg compression devices at the intensive care unit.

Perioperative 30-day mortality was zero. The two patients that were lost to follow-up after being transferred for further care and follow-up at their local hospital on the seventh postoperative day. However, they both were alive according to the Finnish population register at the time of data collection, two and seven years after the operation. Two patients had minor, Clavien-Dindo class 1 and 2

complications while five patients had complications of higher class (*Table 4*). Patient 1 had transient chylus leak and a urinary tract infection. Patient 2 underwent thrombectomy for IVC homograft, had acute kidney injury requiring dialysis, and had melena with no bleeding visible on gastro- or colonoscopy. Patient 3 had thrombectomy and stenting of iliac vein autologous vein graft. Patient 10 underwent relaparotomy for haemorrhage on 8th postoperative day. Patient 15 had spinal ischaemia resulting in paraparesis that had not resolved by discharge from hospital. Patient 16 had transient chylus leak as well as persistent diarrhea attributed to disturbed enteral nervous system function. Patient 17, who had aortic reconstruction with polyethylene, underwent thrombectomy and embolectomies combined with bilateral lower leg fasciotomies due to early thrombosis. This patient was known to have resistance to activated protein C.

The median follow-up time was 27 (0-82) months. In the patients with sarcoma resection, local recurrence developed in six patients with an estimated median local relapse-free time of 43 months. The three-year local-relapse-free survival rate was 61% *(Figure 1*). Metastases were present at the time of surgery in three patients and four additional patients developed metastases during follow-up. Estimated median and 3-year metastasis-free survival were 48 (20-76) months and 68%, respectively *(Figure 2)*.

The estimated median and three-year disease-free survival time for the sarcoma resection patients were 35 (0-74) months and 46%, respectively *(Figure 3)*. Two patients had the metastases resected in a later operation and remained disease free thereafter. Patient 5 with leiomyosarcoma grade 3 had liver metastases resected at 47 months and was disease free at 54 months while patient 10 with undifferentiated pleomorphic sarcoma G3 was disease free at 72 months after having pulmonary metastases resected at 10 months. At the end of the follow-up, eight (47%) patients were disease free, four (24%) were living with sarcoma and five (29%) had died of the disease.

The three-year survival was 80%, and the estimated median survival 66 months. All deaths during follow-up were due to sarcoma. The five patients who died had local recurrence, with three having had the vascular reconstruction as part of a resection of an already recurrent tumor. One of the patients dying with recurrent disease also had metastases at time of surgery and one developed metastases during follow-up.

Two of the 9 patients with IVC reconstruction had late IVC thrombosis with minor symptoms and no intervention was required. One of these reconstructions was an autologous vein graft and the other was bovine pericardium patch repair. Two further patients had IVC obstruction caused by local recurrence of tumor. Patient 17 who had aortic graft thrombosis in the early postoperative period had thrombosis of the graft also 19 months after the operation. Embolectomy and stenting was performed, and the graft remained open for the remainder of the follow-up. Three of the patients did not have imaging studies to assess graft patency.

Literature review

Thirty-seven articles with 110 patients were included in the analysis. (*Table 5.*)[17-53] The median number of eligible patients per article was 2 (1-17) and 19 (51%) articles included only one eligible patient. Fifteen patients (14%) had other vessel reconstructions in conjunction with the IVC reconstruction. Five of these patients had aortic reconstructions while the others had one or both renal veins reconstructed.

As per study design, all the patients included were operated for sarcoma. There were 95 (87%) leiomyosarcomas, 8 (7%) liposarcomas, 3 (3%) rhabdomyosarcomas, 2 (2%) fibrosarcomas, 1 (1%) malignant fibrous histiocytoma, and 1 (1%) synovial sarcoma. Histological resection margins were not reported for 37 of the patients. For those that had data on histological margin available, most tumors (85%) were resected with negative margins. Significant perioperative complications were rare. (*Table 6*)

The majority of patients (58%) remained disease free during a follow-up of 0 to 181 months. Local recurrence or metastases were reported in 47 (43%) of patients. The time of disease recurrence was not reported with sufficient consistency to allow for formal survival analysis. Eight (7%) patients died of sarcoma. The estimated three-year overall survival was 94%. Graft occlusion was reported in 14 (13%) patients. No graft patency data was reported for 20 patients. The estimated three-year patency for the grafts was 82%.

IVC reconstructions

IVC was the most common vessel reconstructed with 103 reconstructions reported. The reconstruction was done with an interposition graft in 90 (87%) patients. Polytetrafluoroethylene (PTFE) was the most common graft material, either ring-reinforced (46 patients (45%)) or without support (22 patients (21%)). Polyethylene terephthalate grafts (10 patients (10%)), homograft (10 patients (10%)) and grafts fashioned from autologous vein (2 patients (2%)) were less frequent. Patch reconstruction was used in 13 (13%) patients.

The range of follow-up for all patients with IVC reconstructions was 0 to 181 months. Data on graft patency was reported for 73 patients (71%), including patients in whom the assessment of graft patency relied on clinical status alone. The range grafts were reported open was 0 to 72 months. Twelve (16%) graft occlusions were identified during follow-up. These included one ring expanded PTFE graft that occluded in the presence of infection 16 days postoperatively following a duodenal leak. In addition, partial graft occlusion was reported in two patients with PTFE grafts, one of which was reinforced. The number of patients included in this review is too small to allow for comparison of occlusion rates in the various graft types. Further, the absence of imaging data during follow-up may have resulted in underreporting of

asymptomatic occlusions. Data on IVC patency was available for 11 (85%) of patch repaired IVC. Only one IVC, patch repaired with polyethylene, occluded during follow-up. One partial IVC stenosis related to patch repair with peritoneum was also reported. (*Table 7.*)

Aortic reconstructions

Reconstruction of the aorta was reported for six patients with polyethylene as the most common (83%) graft material (*Table 8*.). Two of the reconstructions were from suprarenal level down to bifurcation while the other four were infrarenal. No superior mesenteric artery or renal artery reconstructions were done in these patients. Five of the reconstructions were done in conjunction with IVC reconstructions. No perioperative complications were reported for four of the patients. One patient had persistent left chylothorax, which was treated with a pleurovenous shunt, as well as persistent diarrhea. One had persistent diarrhea. No graft occlusions were reported. The follow-up range was 0 to 26 months.

Renal vein reconstructions

Renal vein reconstruction was reported for ten patients in six publications *(Table 8)*. Nine of these were done in conjunction with IVC reconstruction. Various materials were used and material for the repair done without concomitant IVC reconstruction was not specified. One occlusion of a PTFE graft at 24 months was reported. No perioperative complications were reported for six of the patients. Three patients had relaparotomies for hemorrhage. One patient had a Clavien-Dindo class 2 complication, not further specified. The follow-up range was 4 to 66 months.

Iliac artery and vein reconstructions

Iliac vessel reconstruction without IVC reconstruction was reported for four patients in two publications *(Table 8)*. No other vascular reconstructions were done for these patients. One series included three patients in whom ring reinforced PTFE grafts were used. Spiral autologous vein was used in the fourth patient. One of the patients had postoperative ileus that resolved with conservative management. No other perioperative complications were reported. The follow-up range was 5 to 28 months. Two of the three PTFE grafts occluded, at 6 and 10 months.

Other reconstructions

Reconstruction of the superior mesenteric vein and the portal vein with an autologous vein patch was reported in one patient with leiomyosarcoma of the splenic vein. A 15-month follow-up was reported for this patient but no details of the vein patency or oncological outcome were specified.[30] Notably, no reconstructions of other visceral arteries, such as the superior mesenteric artery or the renal arteries, were described.

Discussion

Patients with retroperitoneal soft tissue sarcomas involving major blood vessels were long considered inoperable but advances in oncological therapies and oncovascular surgery have enabled en bloc resection of the tumors and reconstruction of the affected blood vessels. However, most reports available on these patients are small series from single institutes. Furthermore, no established criteria exist for patients considered suitable for oncovascular resection. Here we presented 17 patients with retroperitoneal sarcomas treated by the multidisciplinary oncovascular team in Helsinki University Hospital as well as the results of a comprehensive review of literature to establish the safety and efficacy of these reconstructions.

Resection of the tumor was achieved with histologically wide or marginal margins in 88% of our patients. This is in line with the 85% radical resection rate observed in the patients included in our systematic review. In view of chemo- and radiotherapy not being curative in soft tissue sarcomas and resection margins being the most significant determinant of favorable outcome in the treatment of soft tissue sarcomas, oncovascular approach is likely to have improved disease free survival in these patients.[1-4]

Invasion of the tumor into the wall of the resected vessel, or a tumor arising from the vessel wall, was seen in 53% of our patients. This is comparable to vascular involvement rates of 18-69% previously reported for retroperitoneal sarcomas.[5, 54] However, we were unable to examine invasion rates in the entire literature review population due to inconsistent reporting of histological findings.

The team and the patients should acknowledge that this is major surgery underlined by the fact that the operations took up to 13 hours, median 7 hours and involved major blood loss up to 13 liters. They may be considered a true collaborative effort, as in addition to a vascular surgeon at least one and in many situations all previously mentioned specialists were involved. Postoperative complications occurred in 41% of patients in our series with 24% requiring a reoperation and 12% suffering major organ dysfunction. In the review population, the numbers were 30%, 14% and 3%, respectively. One of the 110 review patients died perioperatively. These data show that even though oncovascular surgery in patients with retroperitoneal sarcomas is not without risks, many of the complications can be managed conservatively or

with non-complicated reoperations and the perioperative mortality is low. Thus, oncovascular surgery may provide hope of remission even for patients with advanced disease.

The three-year disease-free survival was 46% in our patient series. Local recurrence was detected during follow-up in 35% and metastases presented in 41%. This is in line with our review where local recurrence or metastases was reported in 43% during follow-up ranging from 0 to 181 months. The overall three-year sarcoma related mortality in our population was 29%. In comparison only 7% of the review patients were reported to die of sarcoma with the follow-up ranging from 0 to 5 years. This may reflect small population sizes and a publication bias as patients with worse outcome are less likely to be published, whereas our series includes all reconstructed patients fulfilling the criteria. For two of our patients that died, the primary oncovascular surgery was done for a local recurrence. Interestingly, the patient who died with local recurrence of dedifferentiated liposarcoma had the tumor primarily resected with wide margins. The recurrence free and sarcoma specific survival rates here are similar to those reported in patients with retroperitoneal sarcoma who did not require vascular reconstruction.[55] Comparable oncological outcomes between these groups have also been reported in a retrospective matched case-control study.[54] However, comparing the results may be futile as it is impossible to define how many of the patients in our series would have been considered inoperable elsewhere.

Early occlusion of vascular grafts occurred in 18% of our patients and was managed operatively. One of these patients experiences also a late thrombosis of the aortic graft 18 months later. Two late IVC thrombosis were detected, one in an autologous vein graft and one following a bovine patch repair. On a technical note, we used venous compression devices in combination with anticoagulation and no arteriovenous fistulas were reconstructed. Further two patients developed IVC compression by a recurrent tumor. No graft infections occurred in our cohort. Interestingly, only one graft infection was reported in the review patients. The graft was a ring expanded PTFE used for IVC reconstruction and the infection was preceded by duodenal leak. No clear accounts of surgical field contamination were included in the review patient reports. Thus, we were unable to assess whether any particular graft type is more or less prone to infection in that setting.

Our series had a relatively high representation of homograft reconstructions. This reflects our practice of favoring homograft veins as reconstruction material in contaminated clean fields. Similar approach to graft choice has been reported by other centers.[1, 10, 54] Some even report using PTFE for IVC reconstruction only when homograft veins are not available.[16] Homografts have been found to be associated with higher rates of occlusion.[16, 29] In line with this, 3 of the 10 homografts in the review population occluded during follow-up. In our patients, one out of five homograft reconstructions occluded on day 1 and underwent IVC and

renal vein thrombectomy. We did not see any late homograft occlusions. Polyethylene was more common than PTFE as a material choice in this patient series. However, no such preference persists in our clinic.

The major limitations of our case series are the heterogeneity of the pathologies in the patient population, the retrospective nature of the design, and the absence of a control group of patients without vascular reconstructions. In light of the rarity of retroperitoneal sarcomas requiring vascular and especially arterial reconstructions, our study population does, however, contribute significantly to the existing body of literature.

The number of patients in the systematic review presented here is too small to allow for comparisons between the reconstruction materials. The number of patients that we were able to include was partly limited by some of the published case series not including sufficient data to enable identification of the outcomes for individual reconstructions. It is also likely that the review data is influenced by positive bias in that patient cases with favorable outcomes may be offered for publication more frequently. Further, no conclusion can be drawn on the long-term performance of the reconstructions since the median follow-up of the patients is less than 2 years. As most of the patients were alive, and many disease-free, at the end of follow-up, reports with longer follow-up times are called for.

It is also noteworthy that our study does not address the debate on whether IVC does or does not need to be reconstructed after resection for malignancy.[1, 5, 10, 32, 56, 57] However, with our team approach we did not find the reconstruction problematic.

In conclusion, oncovascular surgery enables radical resection required for good local control of retroperitoneal sarcomas and is associated with an acceptable level of complications perioperatively and during follow-up. Thus, through this multidisciplinary approach, it is now possible to offer operative treatment for patients that were previously denied surgery due to vascular involvement of the tumor. More studies are needed to establish any differences between graft materials and to assess long-term graft patency rates.

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	Age (y)/ Sex	Tumour type	First operation?	Resection margins	Vascular invasion	Follow-up time (months)	State at the end of follow-up
Patient 1	59 F	Leiomyosarcoma G2 T2bN0M0	Yes	M	Yes	55	Free
Patient 2	62 F	Leiomyosarcoma G2 T2bN0M1	No	M	No	15	Dead of
Patient 3	56 F	Leiomyosarcoma G2 T2bN0M0	No	M	No	22	Dead of
Patient 4	26 M	Leiomyosarcoma G3 T1bN0M0	Yes	M	Yes	25	Free
Patient 5	58 F	Leiomyosarcoma G3 T2bN0M0	Yes	M	Yes	64	Free
Patient 6	46 M	Leiomyosarcoma G3 T2bN0M1	Yes	M	Arises from IVC	1	Living with
Patient 7	68 F	Leiomyosarcoma G3 T1bN0M0	No	IL	No	0.2	Free
Patient 8	61 F	Leiomyosarcoma G3 T2bN0M0	Yes	M	Yes	68	Living with
Patient 9	40 F	Leiomyosarcoma G3 T1bN0M0	Yes	W	No	29	Free
Patient 10	64 F	Undifferentiated pleomorphic sarcoma G3 T2bN0M0	Yes	M	Arises from IVC	84	Free
Patient 11	59 F	Sclerosing liposarcoma G2 T2bN0M0	Yes	M	Not specified on PAD	12	Dead of
Patient 12	70 M	Myxoid liposarcoma G3 T2bN0M0	No	M	No	43	Dead of
Patient 13	50 F	Dedifferentiated liposarcoma G2 T2bN0M0	No	M	No	48	Living with
Patient 14	63 F	Dedifferentiated liposarcoma G2 T2bN0M0	Yes	W	No	66	Dead of
Patient 15	60 F	Dedifferentiated liposarcoma G3 T2bN0M0	Yes	M	No invasion into aorta; IVC not specified on PAD	27	Free
Patient 16	32 M	Angiosarcoma epithelioides G3 T2bN0M0	Yes	M	Arises from aorta	23	Free
Patient 17	30 F	Thrombosis, retroperiotneal leiomyosarcoma operated two years prior, lung metastases	No	Not applicable	Not applicable	23	Living with

Table 1. **Patient and tumor details.**

	Vessels resected	Vessel reconstruction	Operative details	Vascular complication on follow-up
Patient 1	Infrarenal Aorta and IVC	Aorta with polyethylene prosthesis, IVC with bovine pericardium patch	Temporary axillo-birenal bypass.	IVC thrombosis at 33 months, minor sympoms.
Patient 2	Aorta, IVC, L renal vein	Aorta with polyethylene Y-graft, IVC and L renal vein with homocraft vein	R kidney resected.	IVC thrombosis, thrombectoy on 1st postoperative day. IVC compressed by recurrent tumor at 13 months.
Patient 3	L iliac vein	Autologous vein graft	Preoperative embolisation of the arteries feeding the tumour. Sigma, L kidney and ureter resected.	Iliac thrombosis, thrombectomy and stent on 5th postoperative day.
Patient 4	Aorta, SMA, hepatic artery and R renal artery	Polyethylene	Temporary bypass from axillary artery to hepatica communis, SMA, right renal artery. Pancreas, spleen and L kindery resected.	
Patient 5	IVC	Homograft vein		
Patient 6	IVC	Autologous vein graft	R kidney resected.	Graft thrombosis at 1 month, minor sympoms
Patient 7	IVC and L renal vein	Autologous vein graft	R kidney resected.	
Patient 8	IVC and L renal vein	IVC with homograft vein, renal vein with autologous vein graft	R kidney resected.	
Patient 9	L internal iliac artery and external iliac vein	Artery with PTFE, vein with autologus vein graft		
Patient 10	Aorta, IVC, L renal artery and vein	Arteries with polyethylene, veins with autologous vein graft	Temporary axillo-renal bypass. Gallbladder and R kidney resected.	
Patient 11	Iliaca interna and externa artery and vein	Homocraft vein	Uterus resected.	IVC compressed by recurrent tumor at 4 months.
Patient 12	Common iliac artery and vein	Artery with polyethylene, vena with autologous vein graft		
Patient 13	L renal vein	Autologous vein patch		
Patient 14	Hepatic artery	Autologous vein graft	Pancreaticoduodenectomy and R hemicolon resected.	
Patient 15	Aorta and IVC	Aorta with polyehtylene, IVC Homograft vein	R kidney resected.	
Patient 16	Aorta, IVC patch, coeliac trunc	Aorta, coeliac trunc, SMA, left renal vein and both internal iliac arteries with polyethylene prosthesis, IVC with bovine pericardium patch	Temporary axillo-renal bypass. R kidney resected.	
Patient 17	Aorta	Polyethylene		Graft thrombosis, thrombectomy and lower leg fasciotomies on 1st postoperative day. Graft thrombosis, thrombectomy and stenting at 19 months.

Table 2. Details of vascular reconstructions.

Patient ID	ASA Physical Status Classification	BMI	Duration of operation (h)	Treatment at ICU?	Days at ICU (d)	Nadir Hb	Blood volume loss during surgery	Units of red blood cells transfused (n)	Acute kidney injury perioperatively?
Patient 1	3	32	5.1	Yes	6	91	2700	2	Yes
Patient 2	3	43	6.4	Yes	9	72	4300	4	Yes
Patient 3	4	22	12.6	Yes	3	81	13300	22	No
Patient 4	2	23	7.2	Yes	4	78	4000	5	Yes
Patient 5	3	27	3.6	No	0	114	NA	NA	No
Patient 6	3	22	5.9	Yes	2	93	1500	1	No
Patient 7	3	24	7.3	Yes	2	78	4500	11	No
Patient 8	3	37	5.0	Yes	2	85	2000	1	Yes
Patient 9	2	30	5.5	Yes	3	90	1500	0	No
Patient 10	3	21	11.7	Yes	4	76	5000	10	No
Patient 11	3	30	8.1	Yes	2	98	4150	8	No
Patient 12	2	19	7.0	Yes	2	87	1000	0	No
Patient 13	3	32	5.6	Yes	2	101	550	0	No
Patient 14	2	21	12.3	Yes	2	89	4000	6	No
Patient 15	4	18	7.1	Yes	5	107	3400	6	No
Patient 16	2	21	13.2	Yes	5	89	4700	5	Yes
Patient 17	3	22	5.5	Yes	6	77	1400	5	Yes

Table 3. Perioperative details.

Clavien-Dindo class	Number of patients (n)
None	10
1	1
2	1
3a	0
3b	3
4a	2
5	0

Table 4. **Clavien-Dindo classification of postoperative complications.**

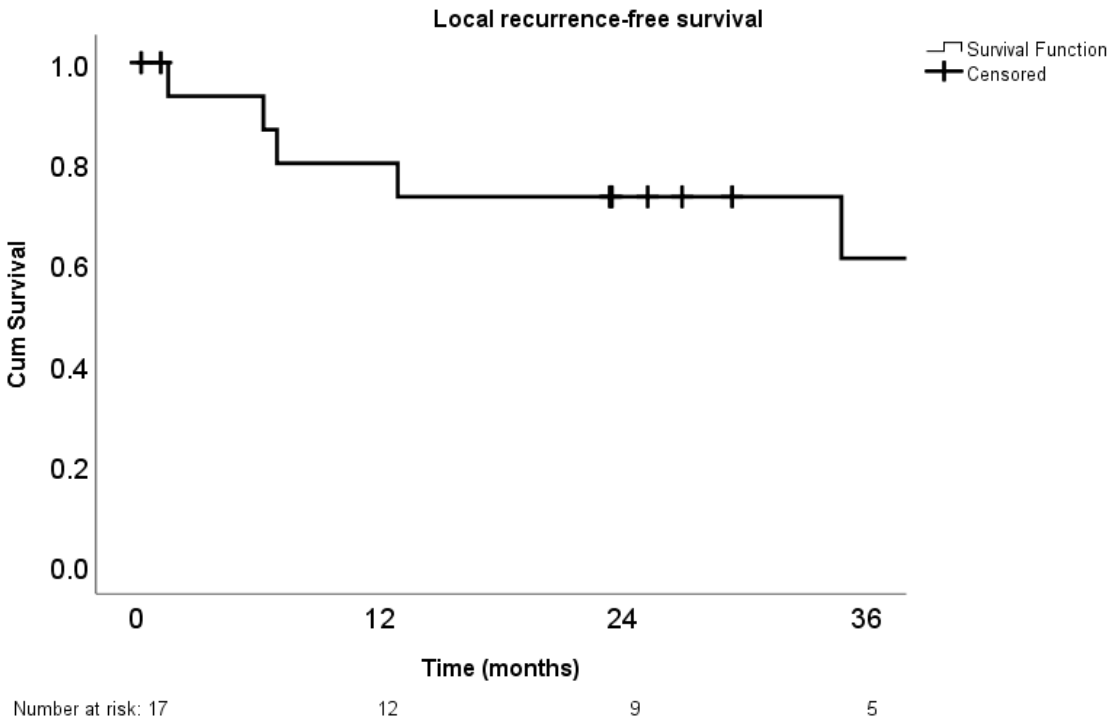


Figure 1. Local recurrence-free survival for patients with intra-abdominal or retroperitoneal sarcoma following oncovascular surgery.

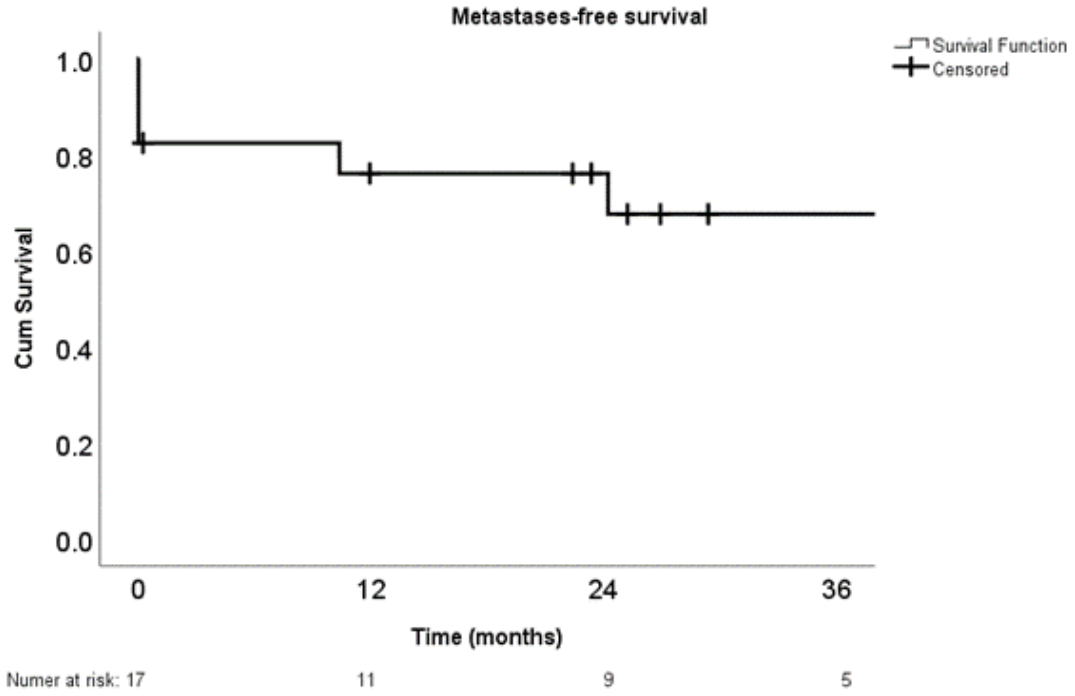


Figure 2. Metastases-free survival for patients with intra-abdominal or retroperitoneal sarcoma following oncovascular surgery.

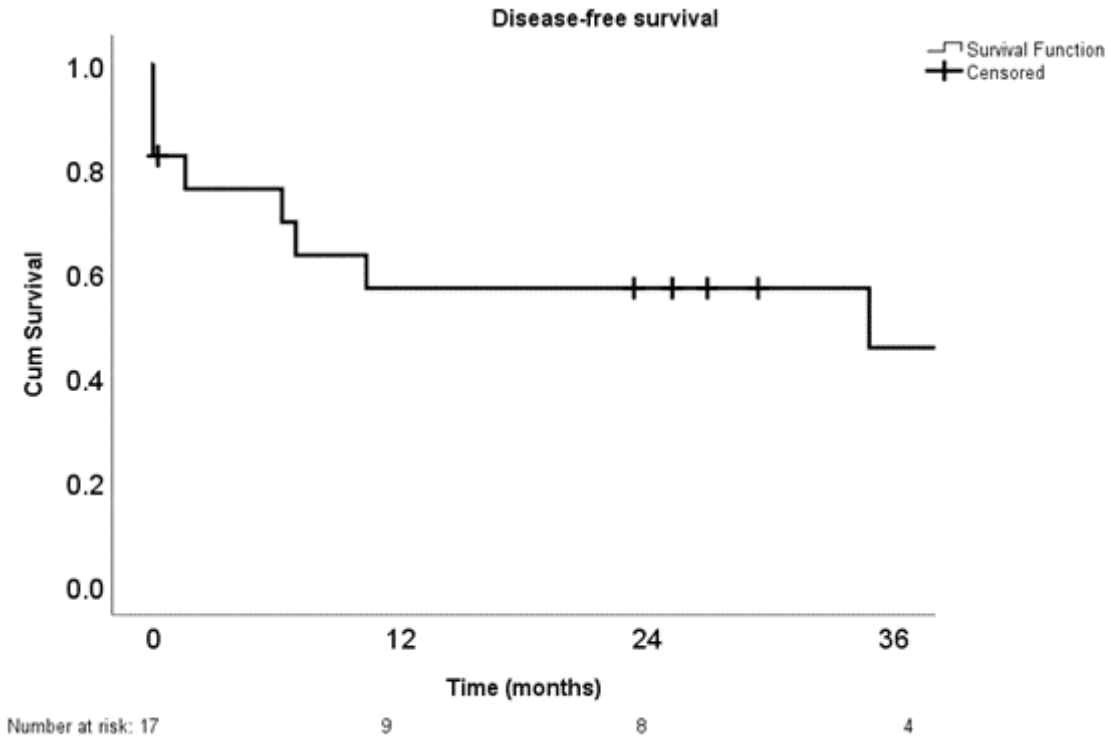


Figure 3. Disease-free survival for patients with intra-abdominal or retroperitoneal sarcoma following oncovascular surgery.

Authors	Year	City	Number of patients total	Number of patients with sarcoma	Time period for the patients	Follow up (months, median (range))
Alkhalili et al[17]	2015	New Mexico	2	2	2013-2016	18 (1-36)
Anaya-Ayala et al[18]	2011	Houston	1	1	2011	2
Angiletta[19]	2001	Bari, Italy	1	1	not stated	36
Arii et al[20]	2003	Tokyo	11	1	1990-2001	11
Bower[21]	2000	Washington, USA	29	17	1990-1999	31 (0-72)
Brown et al[22]	2015	Sydney, Australia	1	1	not stated	5
Caldarelli et al[23]	2002	Pisa, Italy	7	3	1991-2001	24 (12-28)
Caso et al[24]	2008	Tampa, Florida, USA	18	1	1999-2008	6
Cho[25]	2008	Pittsburgh, USA	9	3	1990-2008	30 (12-181)
Coppa et al[26]	2013	Milan, Italy	5	1	2005-2011	50
Coubeau et al[27]	2017	Brussels, Belgium	4	3	2015	4 (4-4)
DuBay et al[28]	2009	Toronto, Canada	1	1	not stated	3
Fiore et al[29]	2012	Milan, Italy	15	11	2004-2011	20 (2-62)
Gage et al[30]	2012	New York, USA	1	1	not stated	15
Grimaldi et al[53]	2019	Rome, Italy	4	1	2009-2017	74
Guerrero[31]	2007	Houston, USA	1	1	not stated	14
Hardwigsen[32]	2005	Marseille, France	5	4	1995-2000	41 (20-52)
Hardwigsen[33]	2001	Marseille, France	14	2	1992-1998	20 (20-20)
Hirohashi[34]	2002	Oska, Japan	1	1	1996	69
Ito et al[35]	1998	Nagoya, Japan	1	1	not stated	18
Kato et al[36]	2013	Sapporo, Japan	23	1	1984-2011	9
Kraybill[37]	1997	Washington, USA	3	3	1993-1994	19 (1-26)
Kwon et al[38]	2003	Seoul, Korea	4	4	1999-2002	24 (61)
Kyriazi et al[39]	2010	Athens, Greece	2	1	not stated	36
Liu et al[40]	2018	Peking, China	10	8	2009-2017	46 (10-67)
Mann[41]	2012	Washington, USA	17	8	1984-2009	50 (18-125)
Nayyar[42]	2010	New Delhi	2	2	not stated	8 (6-9)
Ohman[43]	2013	Houston, USA	1	1	not stated	0
Sarkar[44]	1998	Los Angeles, USA	10	7	1993-1997	18 (7-48)
Stauffer[45]	2008	Jacksonville, USA	1	1	not stated	12
Suzman[46]	2000	New York, USA	1	1	not stated	1
Tameo[47]	2010	Philadelphia, USA	2	2	not stated	10 (4-16)
Teixeira[48]	2017	Sao Paulo, Brazil	7	4	2007-2013	48 (38-57)
Teo[49]	2005	Singapore	4	1	2002	18
Wachtel[50]	2015	Philadelphia, USA	6	6	2005-2013	43 (12-108)
Wang[51]	2012	Changchun, China	2	2	not stated	18 (9-27)
Wise[52]	2012	Rochester, USA	1	1	not stated	0

Table 5. Articles included in the systematic review.

		Number of patients (%)
Resection margin	Negative	62 (56)
	Positive	11 (10)
	Not stated	37 (34)
Clavien-Dindo class	None	59 (54)
	1	4 (4)
	2	9 (8)
	3	15 (14)
	4	3 (3)
	5	1 (1)
	Not stated	19 (17)

Table 6. Resection margins and perioperative complications in the review patients.

Graft type	n (%)	Follow-up (months, range)	Patency info available (n)	Graft occlusion n (% of those for whom info available)	Graft reported patent until (months, range)
All	103 (100)	0-181	84	13 (15)	0-106
Grafts					
PTFE, ringed	46 (45)	0-72	38	4 (11)	0-72
PTFE	22 (21)	1-85	15	2 (14)	1-67
Polyethylene	10 (10)	12-181	8	3 (38)	3-57
Homograft	10 (10)	2-62	10	3 (30)	2-62
Autologous vein	2 (2)	3-5	2	0	3-5
Patches					
PTFE	2 (2)	13-36	1	0	13
Polyethylene	1 (1)	9	1	1 (100)	0
Autologous vein	2 (2)	106-125	1	0	106
Peritoneum	4 (4)	1-4	4	0	1-4
Bovine pericardium	4 (4)	2-51	4	0	0-51

Table 7. Details of IVC reconstructions in review patients.

Vessel	Graft type	Number of patients n (%)	Follow-up (months, range)	Patency info available (n)	Graft occlusion n (% of those for whom info available)	Graft reported patent until (months, range)
Aorta	PTFE	1 (20)	19	1	Not stated	Not applicable
	Polyethylene	5 (83)	0-26	5	0	0-26
Renal vein	All	10	4-66	8	1 (14)	4-57
	PTFE ringed	2 (22)	11-41	2	0	11-41
	PTFE	3 (33)	49-66	3	1	24-57
	Polyethylene	1 (11)	18	1	0	18
	Autologous vein	2 (22)	6-9	0	Not stated	Not applicable
	Peritoneum	1 (11)	0	1	0	0
Common iliac artery and vein	Autograft vein	1	5	2	0	5
Iliofemoral artery and vein	PTFE ringed	1	12	2	1	6
Iliac vein	PTFE ringed	2	24-28	2	1	10-24

Table 8. Details of non IVC vessel reconstructions in the review patients.

Table 1. **Patient and tumor details.** 17 patients with intra-abdominal or retroperitoneal sarcoma treated by the oncovascular team in Helsinki University Hospital from 2010 to 2018 were included in this retrospective study. Vessel walls were infiltrated by, or the origin of, the tumor in seven patients. Resection margins: IL = intralesional, M = marginal, W = wide excision with tumor free margin 2.5 cm or more. Wide excision margin was achieved in 14 (88%) of the patients. At the end of the follow-up, 4 patients were living with the disease; patient 13 with a local recurrence, and patients 6, 8 and 17 with metastases.

Table 2. Details of vascular reconstructions. 40 vessels were reconstructed in the 17 patients with intra-abdominal or retroperitoneal sarcoma treated by the oncovascular team in Helsinki University Hospital from 2010 to 2018. Arterial reconstructions were performed in 11 (65%) of the patients with polyethylene as the most frequently used material. Temporary arterial bypass was used in four operations. Nine IVC reconstructions were performed. Graft thrombosis requiring thrombectomy occurred in three (18%) patients.

Table 3. Perioperative details. 17 patients with intra-abdominal or retroperitoneal sarcoma underwent tumor removal and vascular reconstruction. Most patients were American Surgical Association Physical Status Classification 3. The median operative time was 7.0 hours (range 3.6 to 13.1 hours) and the median estimated blood loss volume 3700 ml (range 550 to 13300 ml). Thirteen (81%) of the patients received red blood cell transfusions. Acute kidney injury was diagnosed perioperatively in six patients. All but one of the patients required intensive care unit (ICU) treatment with a median stay of 3 days (range 0 to 9 days). Perioperative mortality was zero.

Table 4. **Clavien-Dindo classification of postoperative complications.** Postoperative complications occurred in 7 (41%) of the 17 patients that underwent oncovascular surgery for intra-abdominal or retroperitoneal sarcoma. Patient 1 had transient chylus leak and a urinary tract infection. Patient 2 underwent thrombectomy for IVC homograft, had acute kidney injury requiring dialysis, and had melena with no bleeding visible on gastro- or colonoscopy. Patient 3 had thrombectomy and stenting of iliac vein autologous vein graft. Patient 10 underwent relaparotomy for haemorrhage on 8th postoperative day. Patient 15 had spinal ischaemia resulting in paraparesis that had not resolved by discharge from hospital. Patient 16 had transient chylus leak as well as persistent diarrhea attributed to disturbed enteral nervous system function. Patient 17, who had aortic reconstruction with polyethylene, underwent thrombectomy and embolectomies combined with bilateral lower leg fasciotomies. She was known to have resistance to activated protein C.

Figure 1. Local recurrence-free survival for patients with intra-abdominal or retroperitoneal sarcoma following oncovascular surgery. 16 patients underwent tumor resection and vascular reconstruction for

intra-abdominal or retroperitoneal sarcoma. The resection margin was tumor free or marginal in 14 (88%) patients. Local recurrence developed in six patients with an estimated median local relapse-free time of 43 months.

Figure 2. Metastases-free survival for patients with intra-abdominal or retroperitoneal sarcoma following oncovascular surgery. 16 patients underwent tumor resection and vascular reconstruction for intra-abdominal or retroperitoneal sarcoma. Metastases were present at the time of surgery in three patients and four additional patients developed metastases during follow-up. Two of the patients had the metastases later resected. The estimated median and 3-year metastasis-free survival were 48 (20-76) months and 68%.

Figure 3. Disease-free survival for patients with intra-abdominal or retroperitoneal sarcoma following oncovascular surgery. 16 patients underwent tumor resection and vascular reconstruction for intra-abdominal or retroperitoneal sarcoma. The resection margin was tumor free or marginal in 14 (88%) patients. The median follow-up time was 27 (0-82) months. At the end of the follow-up eight (47%) patients were disease free, four (24%) were living with sarcoma and five (29%) had died of the disease. The estimated median and three-year disease-free survival time were 35 (0-74) months and 46%, respectively

Table 5. Articles included in the systematic review. 37 articles were included in the systematic review of literature on vascular reconstructions in patients with retroperitoneal sarcoma.

Table 6. Resection margins and perioperative complications in the review patients. Most retroperitoneal sarcomas in the 110 patients with vascular reconstructions identified through the literature review were resected with negative tumor margins. Perioperative complications were reported to have occurred in 30% of the patients with 14% requiring further surgical intervention. One mortality was reported. The length of time considered as perioperative was not defined in the articles.

Table 7. Details of IVC reconstructions in review patients. Graft repair of IVC was done in 87% of the 110 patients identified through the literature review with reinforced PTFE the most common graft type accounting for 45% of the graft reconstructions. The range of follow-up time was 0 to181 months. IVC occlusion occurred in 14% of all reconstructions. The small group sizes and various pathologies prevent direct comparison of graft type performance based on these data.

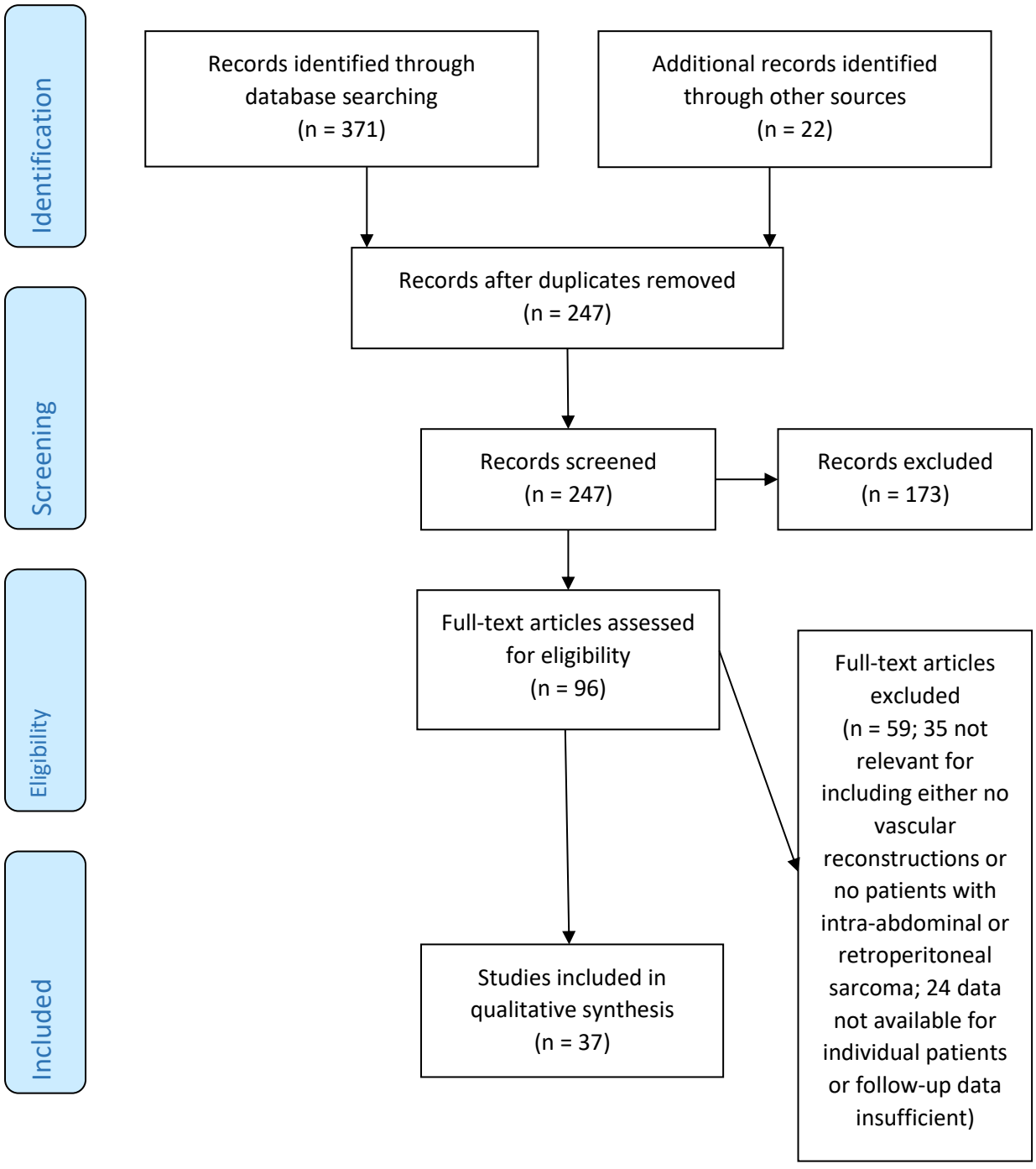
Table 8. Details of non IVC vessel repairs in the review patients. Aortic reconstruction was reported for 6 patients in 5 articles. Two of the reconstructions were from suprarenal level down to bifurcation while the other four were infrarenal. Five of the reconstructions were done in conjunction with IVC reconstruction. Renal vein reconstruction was reported for 10 patients in 6 publications. Nine were done in conjunction with IVC reconstruction. Material for the reconstruction without concomitant IVC reconstruction was not

specified. Iliac vessel reconstruction was reported for 4 patients in 2 publications. No other vascular reconstructions were done in these patients.

Search engine	Search terms
PubMed	((vascular reconstruction) AND (((intra-abdominal) OR intra abdominal) OR retroperitoneal)) AND (((neoplasm) OR cancer) OR tumor)
World of Science	**TOPIC:** (intra* near/2 abdominal* OR retroperitoneal*) *AND* **TOPIC:** (cancer* OR neoplasm* OR tumor* or tumour*) *AND* **TOPIC:** (vascular AND reconstruct*)
MEDLINE	1. (intra* adj2 abdominal*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 2. retroperiton*.mp. 3. 1 or 2 4. neoplasm*.mp. 5. exp NEOPLASMS/ 6. cancer*.mp. 7. (tumor* or tumour*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 8. 4 or 5 or 6 or 7 9. (vascular* adj3 reconst*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] 10. 3 and 8 and 9
SCOPUS	(TITLE-ABS-KEY (intra* W/2 abdominal* OR retroperitoneal*) AND TITLE-ABS-KEY (neoplasm* OR tumor* OR tumour* OR cancer*) AND TITLE-ABS-KEY (vascular* AND reconstruct*)) AND NOT INDEX (medline)

Supplement 1. Search terms for literature search run on 27.1.2020

PRISMA 2009 Flow Diagram



Supplement 2. Flow chart of the systematic review.

Study	Numebr of patients (All / sarcoma patients with vascular reconstructions)	Vessels reconstructed	Materials used	Reported complications	Follow-up
Fueglistaler et al 2006	8/5	Aorta, IVC	Synthetic graft: 100%	C-D II: 1	Median follow-up 14 months (range 1-56 months).
Schwarzback et al 2006	25/20	Aaorta, IVC, iliac vessels, mesenteric vein	Synthetic graft: 81% Synthetic patch: 14% Autologous patch: 5 %	C-D II: 8 C-D III: 2 C-D V: 1	Mean follow-up 19.3 months (IQR 12.4-49.9 months)
Munene et al 2011	4/4	Aorta and IVC	Synthetic graft: 20% Autologous graft: 20% Autologous patch: 60%	C-D II:1 C-D III: 1	Median follow-up 37.5 months.
Quinones-Baldrich et al 2012	47/36	IVC	Synthetic graft: 75% Synthetic patch: 19% Autologous patch: 6%	C-D II: 1 C-D III: 3 C-D IV: 1	Mean follow-up 3.5 years (range 1.5 to 216 months).
Bertrand et al 2016	31/22	IVC, iliac vessels, renal vein	Synthetic graft: 100%	C-D I: 2 C-D II: 2 C-D III: 4 C-D III: 4	Median follow-up 34.4 months (IQR 48.1 months).
Hicks et al 2016	49/14	IVC	Synthetic graft: 37% Allograft: 6% Synthetic patch: 12% Xenograft patch: 45 %	C-D II: 25 C-D III: 6 C-D IV: 6	Median follow-up 19 ± 3.3 months.
Wortmann et al 2017	20/20	Aorta, IVC, iliac vessels	Synthetic graft: 62% Autologous graft: 23% Not specified: 15%	C-D II: 2 C-D V: 1	Median follow-up 72 months.
Blair et al 2018	32/22	IVC	Synthetic graft: 65% Autologous graft: 4% Allograft graft: 13% Patch repair: 17%	C-D III or over: 5	Median overall-survivial 59 months.
Luu et al 2018	16/9	Aorta, IVC, iliac vessels	Synthetic graft: 87 % Autologous graft: 7% Allograft: 7%	C-D II: 9 C-D III: 2	Median follow-up 2.7 years.
Ferrari et al 2019	67/61	Aorta, IVC, iliac vessels	Synthetic graft: 63% Allograft: 42% Synthetic patch: 12% Autologous patch: 2%	C-D III or over: 15	Median follow-up 58 months (IQR 20-85 months).

Supplement 3. Case series excluded from the qualitative analysis.

Supplement 1. Search terms for literature search run on 27.1.2020

Supplement 2. Flow chart of the systematic review. A comprehensive review was performed in three databases to identify 37 articles with data on vascular reconstructions in total of 110 patients with intra-abdominal or retroperitoneal sarcomas. Article selection and data extraction was done by author PH.

Supplement 3. Case series excluded from the qualitative analysis. Ten case series were not included in the qualitative analysis due to the outcomes of individual patients and reconstructions being unidentifiable.