



ORIGINAL RESEARCH ARTICLE

Lymphatic complications after thigh soft tissue sarcoma resection in the era before lymphatic reconstructive surgery – a retrospective cohort analysis

Nicole Lindenblatt^{a*}, Sema Simões de Almeida^{b*}, Isabelle Obrecht^a, Lisanne Grünherz^a, Bruno Fuchs^a, Pietro Giovanoli^a and Semra Uyulmaz^a

^aDepartment of Plastic and Hand Surgery, University Hospital Zurich, Switzerland; ^bDepartment of General Surgery, Cantonal Hospital of Zug, Switzerland

ABSTRACT

Introduction: Patients undergoing curative treatment for soft-tissue sarcomas (STS) of the thigh bear the risk of developing lymphatic fistula and lymphedema. Innovative microsurgical concepts such as primary preventive lymphatic reconstruction show promising results. To discuss the likelihood of lymphatic complications after limb-preserving treatment of STS in the era before lymphatic reconstructive surgery and depending on the sarcoma location in the thigh became paramount in treating these patients.

Methods: We reviewed clinical data of 471 patients who underwent curative lower limb sarcoma treatment at our institution during the period from 2005 to 2019. We allocated patients into cohorts depending on the tumor location in the thigh respecting anatomical compartments as medial, posterior and the anterior compartment. We primarily analyzed incidences of postoperative lymphatic fistula and lymphedema.

Results: We included 69 patients into this study. Mean follow-up period was 36 months. The overall incidence of lymphatic complications was 69.6% (48 of 69 patients). Lymphatic fistulas in general (symptomatic and asymptomatic, $\pm$ lymphedema) were observed in 55% of all patients (38 of 69), whereas lymphedema occurred in 47.8% of all our patients (33 of 69). Lymphatic fistula alone occurred in 15 patients (21.7%) and lymphedema alone occurred in 10 patients (14.5%).

Conclusions: Incidences of lymphatic complications after limb-preserving curative treatment of STS of the thigh are high and vary depending on the exact tumor location. Medial and anterior thigh sarcomas are at high risks for lymphatic complications. Our results might facilitate selecting high-risk patients and aid in justifying preventive microsurgical strategies.

ARTICLE HISTORY

Received 3 February 2025

Accepted 23 May 2025

Published 27 August 2025

KEYWORDS

Lymphatic fistula;
lymphedema; lymphatic
complications; soft-tissue
sarcoma

Introduction

The risk of a previously healthy person receiving a new diagnosis of a soft tissue sarcoma (STS) is between 0.0014 and 0.005% [1]. Despite their rarity, STS can affect people of all ages. Around 40% of all STS develop in the lower body, of which approximately 75% arise above or at the knee [2]. It is well known that the groin is at risk for lymphatic complications due to the anatomic density of lymphatic pathways [2–4]. Sarcoma is one entity where surgical invasiveness cannot be avoided completely due to oncologic safety and an unpredictable behavior [3]. Resection is complex and requires reconstructive surgery in cases where adequate wound closure is not possible or dead space has resulted. The tissues left behind usually suffer from decreased wound healing abilities and are prone to various complications due to radiation-induced poor tissue quality. Patients undergoing curative treatment for thigh STS bear a high risk of developing lymphatic complications such as chronic lymphatic fistula and lymphedema, which negatively affect the well-being of these already physically and psychologically burdened cancer patients [5]. Especially lymphatic fistula may prolong hospital stay, delay adjuvant therapies, and foster the development of lymphedema. Lymphedema,

on the other hand, has a lifelong negative impact on patients' well-being and mobility [6].

Surviving cancer at all costs was the main goal and lymphatic complications have rather been neglected for decades. Nowadays, however, quality of life in cancer survivors has become a fundamental outcome parameter [7]. Modern-day surgeons are aware of potential lymphatic complications, and resections are cut down to what is necessary while respecting lymphatic pathways whenever possible. Innovative microsurgical approaches such as lymphovenous anastomosis (LVA) to prevent or treat lymphatic complications have been introduced and are promoted by many surgeons [8, 9]. However, they can prolong surgery, can be time and personnel-consuming, and bear the risk of being an additional surgical intervention. There is limited information about the incidences of lymphatic complications after limb-preserving treatment of STS in the era before lymphatic reconstructive surgery. The incidences depending on the specific sarcoma location in the thigh are not completely available. Consequently, patients with thigh STS often lack information regarding lymphatic complications and their potential course of healing, making justification for preventive surgical strategies

CONTACT Nicole Lindenblatt ✉ nicole.lindenblatt@usz.ch Department of Plastic Surgery and Hand Surgery, University Hospital Zurich, Rämistrasse 100, 8091 Zurich, Switzerland

 Supplemental data for this article can be accessed online at <https://doi.org/10.2340/jphs.v60.43991>

*These authors share First-authorship.

© 2025 The Author(s). Published by MJS Publishing on behalf of Acta Chirurgica Scandinavica. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), allowing third parties to copy and redistribute the material in any medium or format and to remix, transform, and build upon the material, with the condition of proper attribution to the original work.

difficult. We therefore aimed to analyze incidences of lymphatic fistula and lymphedema after STS resection in the thigh, depending on predefined tumor locations in the era before lymphatic reconstructive surgery at our institution.

Materials and methods

Ethics

Ethical approval to conduct this study was granted by the local institutional review board (KEK BASEC-No. 2020-00001) in 2020.

Study design

This is a retrospective single-center cohort analysis. For the purpose of this study, we reviewed clinical data of 471 patients who underwent curative sarcoma treatment at our institution during the period from 2005 to 2019. We included all male and female patients above 18 years who received curative limb-preserving treatment for thigh STS. Indication and sequencing of radiotherapy and resection was determined by multidisciplinary plenum before treatment. It depends on type of sarcoma, stage and patients' risk factors. Radiotherapy was applied to shrink the tumor before surgery, especially for large, deep or high-grade soft tissue sarcoma. We excluded patients with pre-existing lymphatic or venous diseases, with incomplete relevant data, with sarcomas involving the gluteal area or that extend into the pelvis, as well as with bone sarcomas or with sarcomas arising from cartilage, which usually also represent bone tumors. We excluded all patients where lymphadenectomy was specifically performed. Confounders such as lymphatic pathway injury due to, for example, local flap harvest were not taken into consideration as the defect sizes and flap sizes were not noted in most of the cases. We also excluded patients who rejected our institutional general consent form from further analysis. Additional informed consent was obtained from all

individual patients for whom identifying information is included in this article.

Definition of thigh

We defined the thigh as the area from knee to groin in the anterior aspect and hollow of the knee and gluteal fold in the posterior aspect. We defined the location of STS in the thigh, with respect to the anatomical compartments such as medial, anterior and posterior compartment depending on where most of the tumor volume was apparent. For a more practical description, we further divided the anatomically large anterior compartment into an anterior and a lateral aspect of the thigh. [Figure 1](#) provides a visual representation to clarify the classification used in this study.

Definition of lymphatic complications

Postoperative lymphatic fistula and lymphedema are lymphatic complications. Lymphatic fistula occurs clinically either as an open wound with lymphorrhea or as a symptomatic lymphocele/seroma. In the postoperative course, the surgeons regularly saw their patients in the outpatient clinic and monitored for lymphatic complications. There was no standardized clinical assessment or measurement regarding lymphedema in the majority of the electronic record. Lymphedema was assumed after a venous ultrasound excluded venous insufficiency, whenever postoperative persistent, progressive and irreversible swelling of the limb was described and/ or patients reported subjective symptoms such as prolonged heaviness.

Data collection and analysis

Before conducting this retrospective review, we have performed a sample size analysis to determine the minimum of subjects for

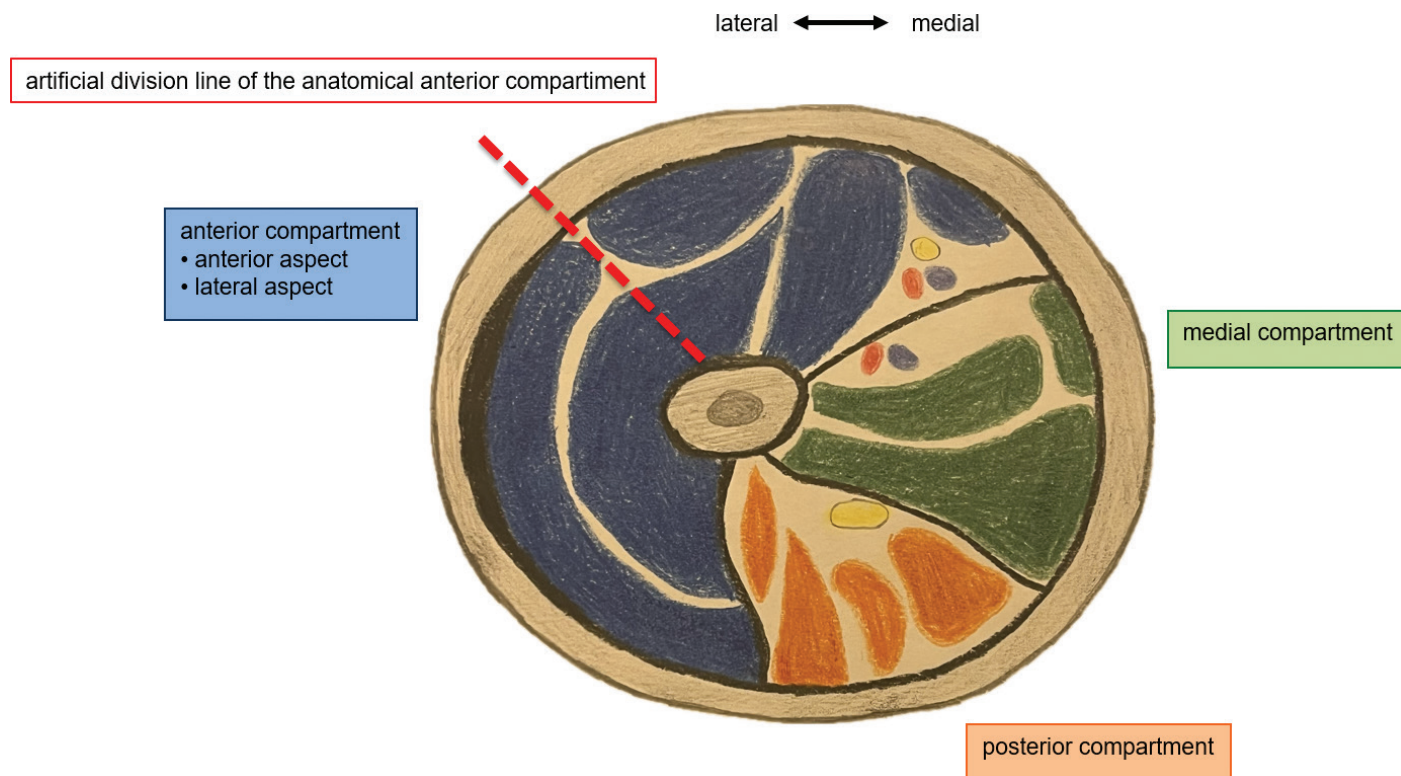


Figure 1. Right thigh cross-section at mid-shaft depicting the defined anatomical locations of sarcomas analyzed in this study.

adequate statistical power ($b = 0.8$). We anticipated a similar or higher incidence in our historical study group [5]. A thorough review of all operation reports and clinical follow-up data between 2005 and 2019 identified 69 patients who met the inclusion criteria and had no reasons for exclusion. Demographic data were abstracted from patients' computerized charts. The number of patients with lymphatic fistula and/or lymphedema was collected for the whole cohort, as well as for subgroups depending on the predefined locations of the tumor in the thigh. This study was conducted according to the guidelines of Strengthening the Reporting of Observational studies in Epidemiology (STROBE). We analyzed the data using Microsoft® Excel Version 14.3.6. (Microsoft Corp., Redmond, WA, USA). Descriptive summary statistics was used to identify central tendencies. Categorical variables were expressed as frequencies or percentages. Pearson's chi-square test was used to determine any significant differences in the incidence rates of lymphatic complications by area. We defined a p -value of < 0.05 as significant.

Results

We included 69 patients into this study. [Supplementary Figure 1](#) depicts the patient selection algorithm.

Demographics

Mean follow-up period was 36 months. The most common STS subtype was liposarcoma (31 of 69, 45%) followed by pleomorphic sarcomas (18 of 69, 26%). The mean tumor volume was 748 cm³. Most patients (56 of 69, 88.9%) received neoadjuvant radiotherapy. Most STS were located in the medial aspect of the thigh (30 of 69 patients, 43.5%). The left lower limb was involved in 34 of 69 patients (49%), and the right lower limb was affected in 35 of 69 patients (51%). Wound complications occurred in 38 patients (55%) and included surgical site infections, skin necrosis, hematomas, wound dehiscence and symptomatic lymphatic fistulas. Revision was necessary in about a third of our patients. In 16 of 69 patients, tumor resection involved major vascular structures and their reconstruction. [Table 1](#) depicts additional demographic data of our study cohort.

Incidence of lymphatic complications

The overall incidence of lymphatic complications after resection of STS in the thigh was 69.6% (48 of 69 patients) ([Table 1](#)). Lymphatic fistulas, that is an open wound with lymphorrhea or a symptomatic lymphocele in general ($\pm$ lymphedema), were observed in 55% of all patients (38 of 69 patients). Almost all of them (36 of 38 patients, 94.4%) had received neoadjuvant radiotherapy. Lymphedema ($\pm$ lymphatic fistulas) occurred in 47.8% of all our patients (33 of 69 patients). Most of them had received neoadjuvant radiotherapy (27 of 33 patients, 81.8%). Lymphatic fistula alone occurred in 21.7% (15 of 69

Table 1. Demographics in our general patient population $n = 69$.

Mean age (years)	55.4 (range 18–85)	
Sex	Female	25
	Male	44
Patients n (%) with BMI		
>25 kg/m ²		28 (40.6)
<25 kg/m ²		41 (59.4)
Radiotherapy n (%)	None	6 (8.7)
	Neoadjuvant	56 (81.2)
	Adjuvant	7 (10.1)
Location of sarcoma in the thigh n (%)	Medial	30 (43.5)
	Posterior	16 (23.2)
	Anterior	18 (26.1)
	Lateral	5 (7.2)
Incision closure n (%)	Primary	47 (68.1)
	Flaps	19 (27.5)
	Free flap	4 (21)
	Local muscle flap	15 (79)
	Skin grafting	3 (4.3)
Lymphatic complications n (%)	Lymphatic fistula	15 (21.7)
Total $n = 48$ (69.6%)	without lymphedema	
	Symptomatic	3 (20)
	Asymptomatic	12 (80)
	Lymphedema	10 (14.5)
	without lymphatic fistula	
	Lymphatic fistula and lymphedema	23 (33.3)
Wound complications n (%)	Infection	24 (34.8)
Total $n = 38$ (55%)	Open lymphatic fistula	3 (4.3)
	other	11 (16)

BMI: body mass index.

patients). Lymphedema alone occurred in 14.5% (10 of 39) of patients, while lymphatic fistula and lymphedema together occurred in 33.4% (23 of 39 patients). In 16 of 69 patients, major vessels were resected and reconstructed. Twelve of them developed lymphatic complications, which is 25% of all patients with lymphatic complications ($n = 48$). Ten had prolonged postoperative swelling. Nine developed recurrent lymphatic fistula with need of intervention, and lymphatic fistula was resolved at 12 months postoperatively in all. After 2, 5 years nine had progressive lymphedema.

Incidence of lymphatic complications depending on tumor location in the thigh

Incidences of lymphatic complications differed depending on the exact tumor location in the thigh. [Table 2](#) summarizes our results. STS in the medial compartment and in the anterior aspect of the thigh had the highest numbers of lymphatic complications. There was no statistically significant relationship between incidence rates of lymphatic complications and tumor location in the thigh, $X^2(1, N = 69) = 4.3969, p = 0.2217$. There was also not enough evidence to suggest an association between tumor location in the thigh and type of lymphatic complication, $X^2(6, N = 48) = 7.3975, p = 0.2856$.

Table 2. Location of sarcoma in all patients ($n = 69$) and type of lymphatic complications in patients with ($n = 48/69$) lymphatic complications.

Location of sarcoma in the thigh	Patients without lymphatic complications ($n = 21/69$; 30.4%)	Patients with lymphatic complications ($n = 48$ of 69; 69.6%)			
		Patients with lymphatic fistula $n = 15/48$	Patients with lymphedema $n = 10/48$	Patients with lymphatic fistula and lymphedema $n = 23/48$	
Medial	7 (23% of $n = 30$)	23 (77% of $n = 30$)	8 (53.3%)	2 (29%)	13 (56.5%)
Posterior	8 (50% of $n = 16$)	8 (50% of $n = 16$)	3 (20%)	2 (20%)	3 (13.0%)
Anterior	4 (22% of $n = 18$)	14 (78% of $n = 18$)	3 (20%)	6 (60%)	5 (21.7%)
Lateral	2 (40% of $n = 5$)	3 (60% of $n = 5$)	1 (6.7%)	0	2 (8.7%)

Illustrative case 1: Historical approach

A 76-year-old female, a heavy smoker with a body mass index (BMI) of 19.1 kg/m², suffered from a high-grade pleomorphic sarcoma in her left musculus adductor magnus. She underwent neoadjuvant radiotherapy (25 × 2 Gy = 50 Gy) over 4 weeks. She had also been diagnosed with metastasized lung cancer recently. Chemotherapy, immunotherapy and surgery were scheduled after sarcoma treatment. Her case had been discussed in our hospital's multidisciplinary tumor conference beforehand. Two months after the neoadjuvant radiotherapy for thigh sarcoma, a new magnetic resonance imaging depicted a stable 2.3 × 1.3 × 1.0 cm sharp lesion and perifocal edema of nearby tissues. Sarcoma resection was conducted via a dorsomedial approach and included a skin spindle, subcutaneous tissue, musculus semitendinosus and parts of the musculus semimembranosus (Supplementary Figures 2–5). We put one suction drain into the wound before direct closure. The early postoperative course was uneventful. The drain was removed on postoperative day seven once the drain output was less than 30 cc/ 24 h. The specimen weighed 185 g and was 17 × 7 × 6 cm large including skin, subcutaneous tissue and muscle as well as tendon (over a distance of 5 cm). The skin spindle measured 12.5 × 5.2 cm. An intramuscular white and well-defined lesion of 1.5 × 2.7 × 1 cm was identified on further histopathological examination. After hospital discharge, the patient presented herself twice for a localized swelling and seroma aspiration. Three weeks after surgery, the patient presented herself again with persistent swelling and this time major discomfort. Ultrasound examination revealed a large (17.5 × 6 × 7 cm) septate seroma, which was aspirated and sampled for microbiological testing. Revision surgery was scheduled. Antibiotic therapy was administered intravenously after *Staphylococcus aureus* was detected in the samples. We performed five surgical debridements bridged by a vacuum assisted closure system over a period of 3 months until healthy granulation tissue was achieved [10]. After a second attempt of split-thickness skin grafting, the wound was finally closed. Two years later, the patient was alive with no evidence of disease. The metastasized lung cancer was treated and in remission. She had developed lymphedema stage II (International Society of Lymphology) and needed custom-made compression garments, thorough skin care, and regular manual lymphatic drainage.

Illustrative case 2: Contemporary approach

A 47-year-old male presented with a diagnosis of a spindle- and pleomorphic-cell undifferentiated sarcoma, located primarily in the right sartorius muscle compartment (11 × 5 × 5 cm). The patient also has a history of chronic gout, for which medical treatment was occasional. His case had been discussed in our hospital's multidisciplinary tumor conference. According to its recommendation, the patient underwent neoadjuvant radiation therapy which consisted of a total dose of 50 Gy, delivered in 25 fractions (2 Gy per fraction) over 2 months. Post-radiotherapy and preoperative staging revealed signs of tumor liquefaction, indicating a good response, but with an increase in size. Tumor resection was performed through a longitudinal incision directly over the tumor in the proximal medial thigh (Supplementary Figures 6–9). The fascia was widely exposed in a spindle-shaped fashion. Access was gained over the adductor compartment, leaving the fascia over the tumor, allowing direct access to the neurovascular bundle. The proximal portion of the sartorius muscle was transected. Medially and proximally, the femoral vessels were identified. Dissection continued distally along the neurovascular bundle, preserving the adventitia on the tumor. Lateral dissection of the tumor was performed through the vastus medialis muscle, leaving a muscle layer over the tumor, including the fascia of the vastus medialis. The

same approach was followed from distal after transection of the sartorius muscle. The septum was then transected under protection of the femoral neurovascular bundle. The tumor could be completely resected. Preoperatively, a pedicled vertical rectus abdominis muscle flap was considered as an option to reduce potential dead space. Intraoperatively, we decided to advance the remaining vastus medialis muscle into the resection field, which appeared to be sufficient. The muscle was freed proximally, distally, and laterally and then transposed medially to cover the exposed femoral neurovascular bundle and reduce dead space. Since the tumor resection involved lymphatic pathways, at the initial surgery after tumor resection, we visualized severed lymphatic vessels using Indocyanine-Green fluorescence (ICG) [11]. Microscopic lymphatic vessel ligation was performed whenever a suitable vein for anastomosis was not found. Two patent lymphovenous anastomoses were performed after resection. A suction drain was inserted and removed after 13 days. Four weeks later, the patient presented with a palpable swelling distally underneath the stable scar and 20 cc clear liquid was aspirated percutaneously. Another 4 weeks later, an MRI revealed a larger septate seroma proximally along with skin changes due to radiation (radioderm). The patient reported minor discomfort by the fluid accumulation. Due to its configuration, we decided to observe its clinical course. Placement of a suction drain was not possible. Three years later, the patient had no clinical signs of lower limb edema and had no complaints regarding the former surgical site.

Discussion

Case discussion

Our first illustrative case demonstrates a typical clinical scenario of lymphatic complications after extensive STS resection in the thigh before routine lymphatic reconstructive surgery at our department. The patient was a heavy smoker, had a diagnosis of metastasized lung cancer, and was potentially malnourished with a BMI of 19.1 kg/m². All aspects may allow questioning the overall invasiveness of sarcoma treatment. An unconventional dorsomedial approach to the medial compartment of the thigh was chosen and a large spindle of skin and subcutaneous tissue was excised from this area, most likely without adequately respecting the lymphatic pathways. The sarcoma was described as a sharp lesion that had not changed in size after neoadjuvant radiotherapy. Resection involved multiple nearby muscular structures. It is arguable whether primary closure was the correct choice, and the dead space was sufficiently obliterated in the beginning. Intraoperatively no primary preventive measures were taken such as visualization of severed lymphatics, microscopic lymphatic vessel ligation or immediate LVA. The patient was readmitted to the ward with large, infected lymphocele and a closed wound. She had slight discomfort but no fever. The decision for revision surgery might have been taken hastily. A conservative approach could have been attempted by transcutaneous placement of a suction drain and intravenous antibiotic therapy. In the following surgeries, an attempt to detect severed lymphatics under the microscope and either ligate or deviate them into the venous system might have shortened the course of healing. Our second illustrative case shows a more contemporary approach. Due to the radiation and the associated potential wound healing complications, as well as the tumor's close proximity to the femoral neurovascular bundle, dead space avoidance/reduction was one major goal alongside oncologic safety. The initial plan to use a vertical rectus abdominis muscle VRAM flap was suspended after tumor resection. The remaining vastus medialis muscle was freed and advanced into the operating field covering the exposed vascular structures and obliterating dead space. Immediate LVA and microscopic lymph vessel ligation were performed meticulously.

When patient appeared to have a septate seroma and after the skin changes were identified as radioderm with a stable scar, a conservative approach with close observation was chosen over an aggressive revision surgery.

Wound complications, risk factors and quality of life after limb-preserving STS surgery

Wound complications after limb-preserving STS surgery are common. Multiple reports show a general range of 15–44% of major wound complications in limb sarcomas and up to 87% in medial thigh surgery [12–14]. Our small and heterogeneous study population did not allow for credible risk factor analysis. In fact, risk factors for wound complications in general as well as for lymphatic complications are well analyzed in studies with larger cohorts. Authors have reviewed 256 cases of STS treated surgically between 2000 and 2011. Diabetes, smoking, obesity, tumor diameter, tumor location in the proximal lower limb and preoperative radiotherapy were shown to be independent predictors for major wound complications on multivariate analysis [15]. Another retrospective review analyzed 148 patients who underwent thigh sarcoma resection and reconstruction by a plastic surgeon at the Mayo Clinic between 1997 and 2014 [16]. Risk factors for the development of lymphedema included defect location in the medial thigh, arterial resection, arterial reconstruction and a history of cardiac disease. It is important to note that in our study cohort, 25% of all patients with lymphatic complications had undergone major vessel resection and reconstruction. In future studies, these patients will be considered as a separate cohort, and this might have biased our result. Noninfectious wound dehiscence may be secondary to lymphedema or represents an early indicator of patients who will ultimately develop lymphedema. In fact, noninfectious wound dehiscence often occurs due to lymphatic fistula. It becomes clear that patients undergoing curative treatment for STS of the thigh bear a high risk of developing lymphatic complications such as chronic lymphatic fistula and secondary lymphedema due to the density of lymphatic pathways located in that area. Both conditions can be disastrous for these already physically and psychologically burdened patients [6, 13]. Today, quality of life of cancer survivors is an important outcome parameter. In a large multicenter study, 1,113 adult sarcoma patients were assessed using standardized validated questionnaires for health-related quality of life outcomes (HRQoL) [17]. HRQoL differed between tumor sites with lower extremities performing the worst. Due to our long study period over 14 years, it was not possible to contact patients for a detailed analysis of how these complications affected their quality of life retrospectively. Many had either died, or we had simply lost their contact.

Incidences of lymphatic fistula and lymphedema depending on sarcoma location in the thigh

It is well known that the medial thigh is prone to lymphatic complications due to the anatomical condition with condensed lymphatic vessels and lymph nodes in this area. Thus, it is important to know incidences of lymphatic complications of every aspect of the thigh, so that surgeons can have a substantiated discussion with patients. One study found that the medial and anterior thigh bear the highest risk of development of lymphedema and has found that the risk of the development of lymphedema was 12% during an average follow-up of 26 months [16]. Our study shows a comparable incidence of 14.5% for the development of lymphedema alone in patients with thigh STS resection over 36 months. In our cohort, the medial compartment and anterior aspect of the thigh were at highest risk for developing lymphatic complications, followed by the lateral aspect and posterior

compartment of the thigh. Lymphatic fistula and lymphedema together occurred simultaneously in 33.4% patients. Lymphatic fistula alone occurred in 21.7% of our patients. Lymphedema in general occurred in almost half of all our patients (47.8%). We did not find statistical significance in our results. To our knowledge, incidences of lymphatic fistula depending on exact tumor location in the thigh have not been reported as an independent condition so far. It is important to point out lymphatic fistula as a separate condition, as it may be an early predictor for the development of lymphedema. The risk for lymphedema after thigh STS resection may even be higher than reported in literature so far. Lymphatic fistula management for our patients from 2015 was conducted according to our previously published algorithms [18, 19].

Other previous studies have helpfully clarified standard care algorithms in the presence or absence of dead space. Usually, a stepwise approach, combining lymphatic surgery principles and plastic surgery techniques, leads to an effective treatment algorithm where surgical options are wound tailored [20].

Incidence of lymphatic complications in an era before lymphatic reconstructive surgery and its implications on modern day STS surgeons

With the priority of oncologic safety, surgeons today are aware of the dramatic impact of lymphatic complications on morbidity and well-being of their cancer patients. In our analysis, we obtained an overall incidence of lymphatic complications after resection of STS in the thigh of 69.6% (48 of 69 patients). This number appears rather high, and most likely does not represent modern day outcomes. Several factors might have influenced our results. Our cases are heterogeneous and the study period over 14 years is long. In our hospital, multiple surgeons and different surgical approaches were involved in the resection of tumors and tissue reconstruction. Our results show that the physiology and anatomy of the lymphatic system and its implications on overall outcomes were not well known or appreciated in earlier times.

Considering that the overall incidence of lymphatic complications after STS resection in the thigh is 69.6%, there is a clear need for preventive measures when possible before, during and after resection and treatment algorithms. Our institutional approach to treat STS patients has changed significantly over the duration of this retrospective review [11, 18, 19]. We continue to discuss all cases in multidisciplinary settings. Treatment recommendations for several STS types follow a trend toward personalized therapy based on tumor molecular profiling [21, 22]. Lower radiotherapy doses are necessary and advanced chemotherapeutical options are available. Neoadjuvant immunotherapies as well as targeted therapies offer new possibilities. Their addition into a treatment plan aids in reducing local side effects of radiotherapy and surgical invasiveness. During resection, we preserve lymphatic and vascular vessels, whenever possible oncologically. As a standard approach, we visualize severed lymphatics under the microscope before wound closure and perform immediate LVA and/or multiple microscopic lymphatic vessel ligations [11]. We have developed algorithms on how to manage recurrent and complicated lymphocele effectively in different clinical scenarios [18, 19].

The most promising potential to decrease lymphatic fistula formation might remain the obliteration of the surgically created space and minimization of tissue dissection [23, 24]. Dead space obliteration or avoidance at initial surgery has in fact been shown to be crucial for uneventful wound healing in oncologic thigh defects. Moderate size superficial defects in non-irradiated patients are often well-addressed with pedicled perforator flaps. The use of free flaps is

Table 3. Concepts for prevention and treatment of lymphatic complications after oncologic surgery.

	Concepts for prevention and treatment of lymphatic complications after oncologic surgery in the upper and lower limb						Special topic: Breast cancer	
Name	LYMPHA <i>Lymphatic Microsurgical Preventive Healing Approach</i>	LNTV <i>Lymph Node-to-Vein Anastomosis</i>	VLNT/LTT <i>Vascularized Lymph node Transfer/ Lymphatic Tissue Transfer</i>	LIFT <i>Lymph Interpositional Flap Transfer</i>	LYFT <i>Lymphatic Flow Through</i>	LYST <i>Lymphatic System Transfer</i>	T-LAR <i>Targeted Lymphatic Axillary Repair</i>	T-BAR <i>Total Breast Anatomy Restoration</i>
Concept	Performing prophylactic bypass of transected lymphatics to nearby venous outflow tracts at the time of the oncologic operation	Capsulotomy of previously identified functional lymph node, protecting all efferent and afferent vessels; a side-to-end anastomosis with nearby vein	Lymphatic tissue including lymphatic vessels and lymph nodes are transferred with a microvascular pedicle	Axial transfer of flaps with lymph collecting vessels inside them aimed at bridging the lymphatic vessels in the defect zone for lymph flow restoration: Lymph axially concept	Using a flap pedicle run-off as recipient vein for multi lymphatic into vein anastomoses (MLVA)	Flap transfer with vascularized afferent lymphatic vessels along with their draining vascularized lymph nodes as a unit	Axillary reverse mapping before sentinel lymph node biopsy, implementation of LVA if necessary	A compound abdominal flap containing lymph nodes, with double vascularization and in some cases with LLA, is raised and transferred.
Benefits/ Limitations	No donor site Depends on availability of suitable veins in potentially radiated site Immediate effects are expected	Can drain numerous collectors in a lymphosome, offering an efficient addition or alternative to LVA	Effects rely on lymphangiogenesis and are postponed until afferent and efferent lymphatics develop Certain risk of lymphatic complications depending on donor site Potential deformities at recipient site Less attractive as primary procedure	No use of donor lymph nodes No microsurgical anastomosis Defect coverage Minimal risk of donor site lymphatic complications Effects rely on lymph-angiogenesis, are postponed until afferent and efferent lymphatics develop	Brings a quality vein into defect zone that can receive lymphatic flow more distally on the thigh, before it reaches the resected or jeopardized area Defect coverage Minimal risk of donor site lymphatic complications Immediate effects are expected	Increased complexity of raising flaps Lesser degree of lymph-angiogenesis needed Immediate effects are expected Defect coverage	See LYMPHA	See LYST

LVA: lymphovenous anastomosis.

suggested for coverage of extensive defects, especially in the setting of previous irradiation [25]. Factors shown to be predictive of requiring a free flap included wide defects (mean size 13.6 cm for free flaps versus 8.9 cm for all other types of reconstruction, $p = 0.03$) and location in the middle third of the thigh ($p = 0.001$) [26].

Recently, the transfer of flaps containing lymphatic tissues or addressing severed lymphatic collectors at the recipient site has

gained worldwide attention in the treatment and prevention of lymphatic complications over the last decade. Remarkably, one must emphasize that Sir Harold Gillies has described the concepts of flap and lymphatic shunt techniques in 1935 [27]. This technique of filling the lymphatic gaps with healthy collectors has been refined and is being widely popularized under the name LIFT (Lymph-Interpositional Flap Transfer) [28]. This treatment approach relies on

the spontaneous regeneration and reconnection of lymphatics without the need for microvascular anastomosis [29]. It has been reported as the lymph-axiality concept, which suggests possibility of lymphatic reconstruction using flap transfer without lymph node or supermicrosurgical lymphatic anastomosis. Several other technical approaches have been developed by the microsurgical community to counteract or prevent the problem of complex lymphatic leaks-lymphedema-fistulas. Table 3 comprehensively summarizes currently available and most relevant strategies that address this complex topic [30–39].

The retrospective nature and its limited sample size represent a limitation of this surgical case series. Given the complexity of the disease and diversity of treatments, this study might serve as a starting point for future prospective and controlled studies with larger cohorts in this field. Incorporating standardized assessment methods will improve the reliability of future studies. Still, our results are of importance. Lymphatic complications are serious complications and increase the overall morbidity. The incidence of developing lymphatic complications varies depending on the location of the sarcoma in the thigh. The medial and anterior thigh bear the highest risk for lymphatic complications. Awareness of the development of lymphatic complications after resection of thigh STS, depending on particular areas of the thigh, will improve prophylactic measures such as considerations for general surgical invasiveness, early diagnosis and treatment of lymphedema. Patients can be informed better and educated about their potential course of healing after sarcoma resection depending on their individual tumor location. The results will allow patients to have an informed discussion with their treatment team. Our results might facilitate selecting high-risk patients and aid in justifying preventive microsurgical strategies.

Disclosure statement

Nicole Lindenblatt acts as scientific advisor and consultant for Medical Microinstruments (MMI). The other authors declare that they have no potential conflict of interest with respect to the research, authorship or publication of this article. No funding received.

References

- [1] DeVita VT, Rosenberg SA, Lawrence TS. DeVita, Hellman, and Rosenberg's cancer: principles & practice of oncology. 11th ed. Wolters Kluwer; 2018. Riverwoods, Illinois, USA
- [2] Collin C, Hadju S, Godbold J, et al. Localized, operable soft tissue sarcoma of the lower extremity. *Arch Surg*. 1986; 121(12): 1425–1433. <https://doi.org/10.1001/archsurg.1986.01400120075013>
- [3] Friedmann D, Wunder JS, Ferguson P, et al. Incidence and severity of lymphoedema following limb salvage of extremity soft tissue sarcoma. *Sarcoma*. 2011; 2011(1): 289673. <https://doi.org/10.1155/2011/289673>
- [4] Sanniec KJ, Swanson S, Casey WJ, et al. Predictive factors of wound complications after sarcoma resection requiring plastic surgeon involvement. *Ann Plast Surg*. 2013; 71(3): 283–285. <https://doi.org/10.1097/SAP.0b013e31827c7973>
- [5] Chang AE, Steinberg SM, Culnane M, et al. Functional and psychosocial effects of multimodality limb-sparing therapy in patients with soft tissue sarcomas. *J Clin Oncol*. 1989; 7(9): 1217–1228. <https://doi.org/10.1200/JCO.1989.7.9.1217>
- [6] Schreiber D, Bell RS, Wunder JS, et al. Evaluating function and health related quality of life in patients treated for extremity soft tissue sarcoma. *Qual Life Res*. 2006; 15(9): 1439–1446. <https://doi.org/10.1007/s11136-006-0001-4>
- [7] Kruiswijk AA, Van de Sande MAJ, Verhoef C, et al. Changes in health-related quality of life following surgery in patients with high-grade extremity soft-tissue sarcoma: a prospective longitudinal study. *Cancers (Basel)*. 2024; 16(3): 547. <https://doi.org/10.3390/cancers16030547>
- [8] Campione E. Immediate lymphatic reconstruction: The future of lymphedema risk reduction? *Rehabil Oncol*. 2023; 41(3): 157–159. <https://doi.org/10.1097/01.REO.0000000000000344>
- [9] Chun MJ, Saeg F, Meade A, et al. Immediate lymphatic reconstruction for prevention of secondary lymphedema: a meta-analysis. *J Plast Reconstr Aesthet Surg*. 2022; 75(3): 1130–1141. <https://doi.org/10.1016/j.bjps.2021.11.094>
- [10] Marangi GF, Segreto F, Coppola MM, et al. Management of chronic seromas: a novel approach with the use of vacuum assisted closure therapy. *Int Wound J*. 2020; 17(5): 1153–1158. <https://doi.org/10.1111/iwj.13447>
- [11] Uyulmaz S, Grünherz L, Giovanoli P, et al. Primary lymphovenous anastomosis after extended soft tissue resection in the medial thigh for reduction of lymphocele and lymphedema. *Ann Plast Surg*. 2024; 93(2): 221–228. <https://doi.org/10.1097/SAP.0000000000003994>
- [12] Baldini EH, Lapidus MR, Wang Q, et al. Predictors for major wound complications following preoperative radiotherapy and surgery for soft-tissue sarcoma of the extremities and trunk: importance of tumor proximity to skin surface. *Ann Surg Oncol*. 2013; 20(5): 1494–1499. <https://doi.org/10.1245/s10434-012-2797-1>
- [13] Focássio CCM, Gamboa RAB, De Marco LFS, et al. Treatment of lymphocele with negative pressure wound therapy post inguinal mass excision: a case-report. *Int J Surg Case Rep*. 2020; 66: 43–47. <https://doi.org/10.1016/j.ijscr.2019.11.017>
- [14] Slump J, Bastiaannet E, Halka A, et al. Risk factors for postoperative wound complications after extremity soft tissue sarcoma resection: a systematic review and meta-analyses. *J Plast Reconstr Aesthet Surg*. 2019; 72(9): 1449–1464. <https://doi.org/10.1016/j.bjps.2019.05.041>
- [15] Moore J, Isler M, Barry J, et al. Major wound complication risk factors following soft tissue sarcoma resection. *Eur J Surg Oncol*. 2014; 40(12): 1671–1676. <https://doi.org/10.1016/j.ejso.2014.10.045>
- [16] Wu P, Elswick SM, Akhavan AA, et al. Risk factors for lymphedema after thigh sarcoma resection and reconstruction. *Plast Reconstr Surg Glob Open*. 2020; 8(7): e2912. <https://doi.org/10.1097/GOX.0000000000002912>
- [17] Eichler M, Hentschel L, Richter S, et al. The PROSa Study Group. The health-related quality of life of sarcoma patients and survivors in Germany-cross-sectional results of a nationwide observational study (PROSa). *Cancers (Basel)*. 2020; 12(12): 3590. <https://doi.org/10.3390/cancers12123590>
- [18] Uyulmaz S, Planegger A, Grünherz L, et al. Lymphovenous anastomoses and microscopic lymphatic ligations for the treatment of persistent lymphocele. *Plast Reconstr Surg Glob Open*. 2021; 9(2): e3407. <https://doi.org/10.1097/GOX.0000000000003407>
- [19] Uyulmaz S, Puippe G, Büyükyüz N, et al. Sclerotherapy with OK-432 for the treatment of symptomatic lymphocele after lymph node dissection: a retrospective comparative cohort study. *Ann Plast Surg*. 2020; 85(4): 407–412. <https://doi.org/10.1097/SAP.0000000000002251>
- [20] Watfa W, Campisi C, Ryan M, et al. Lymphatic leaks of the thigh and inguinal region: combined plastic surgery approaches for an effective treatment algorithm. *Ann Plast Surg*. 2020; 85(6): 661–667. <https://doi.org/10.1097/SAP.0000000000002310>
- [21] Desai IME, Rothermundt C. Personalized therapy of sarcomas. *Cancers (Basel)*. 2023; 15(20): 5110. <https://doi.org/10.3390/cancers15205110>
- [22] Montella L, Altucci L, Sarno F, et al. Toward a personalized therapy in soft-tissue sarcomas: state of the art and future

- directions. *Cancers* (Basel). 2021; 13(10): 2359. <https://doi.org/10.3390/cancers13102359>
- [23] Aho JM, Nickerson TP, Thiels CA, et al. Prevention of postoperative seromas with dead space obliteration: a case-control study. *Int J Surg*. 2016; 29: 70–73. <https://doi.org/10.1016/j.ijssu.2016.03.004>
- [24] Bercial ME, Neto MS, Calil JA, et al. Suction drains, quilting sutures, and fibrin sealant in the prevention of seroma formation in abdominoplasty: which is the best strategy? *Aesthetic Plast Surg*. 2012; 36(2): 370–373. <https://doi.org/10.1007/s00266-011-9807-8>
- [25] Brunetti B, Morelli Coppola M, Tenna S, et al. Thigh reconstruction between form and function: an algorithm for flap selection based on a series of 70 oncological patients. *Microsurgery*. 2024; 44(1): e31121. <https://doi.org/10.1002/micr.31121>
- [26] Elswick SM, Wu P, Arkhavan AA, et al. A reconstructive algorithm after thigh soft tissue sarcoma resection including predictors of free flap reconstruction. *J Plast Reconstr Aesthet Surg*. 2019; 72(8): 1304–1315. <https://doi.org/10.1016/j.bjps.2019.04.016>
- [27] Franchi A, Schnegg JR, Di Summa PG. Taps, wicks, bridges and LIFTs: clarification on the origins of lymphatic flaps. *J Plast Reconstr Aesthet Surg*. 2024; 98: 240–243. <https://doi.org/10.1016/j.bjps.2024.09.018>
- [28] Yamamoto T, Yamamoto N, Kageyama T, et al. Lymph-interpositional-flap transfer (LIFT) based on lymph-axiality concept: simultaneous soft tissue and lymphatic reconstruction without lymph node transfer or lymphatic anastomosis. *J Plast Reconstr Aesthet Surg*. 2021; 74(10): 2604–2612. <https://doi.org/10.1016/j.bjps.2021.03.014>
- [29] Taylor GI, Pan WR. *The angiosome concept and tissue transfer*, Thieme, Stuttgart, Germany (2013).
- [30] Guillier D, Guiotto M, Cherix S, et al. Lymphatic flow through (LyFT) ALT flap: an original solution to reconstruct soft tissue loss with lymphatic leakage or lower limb lymphedema. *J Plast Surg Hand Surg*. 2023; 57(1–6): 216–224. <https://doi.org/10.1080/2000656X.2022.2039680>
- [31] Di Summa PG, Guillier D. The Lymphatic Flow-Through (LyFT) flap: proof of concept of an original approach. *J Plast Reconstr Aesthet Surg*. 2020; 73(5): 983–1007. <https://doi.org/10.1016/j.bjps.2020.01.014>
- [32] Yoshimatsu H, Cho MJ, Karakawa R, et al. The role of lymphatic system transfer (LYST) for treatment of lymphedema: a long-term outcome study of SCIP flap incorporating the lymph nodes and the afferent lymphatic vessels. *J Plast Reconstr Aesthet Surg*. 2025; 101: 15–22. <https://doi.org/10.1016/j.bjps.2024.11.052>
- [33] Martini F, Meroni M, Scaglioni MF. Pedicled SCIP-based vascularized lymphnode and lymphatic vessels transfer for deep lymphatic system reconstruction and dead space obliteration after medial thigh sarcoma resection: a case report. *Microsurgery*. 2024; 44(5): e31205. <https://doi.org/10.1002/micr.31205>
- [34] Lipman K, Luan A, Stone K, et al. Lymphatic microsurgical preventive healing approach (LYMPHA) for lymphedema prevention after axillary lymph node dissection – a single institution experience and feasibility of technique. *J of Clinl Med*. 2022; 11(1): 92. <https://doi.org/10.3390/jcm11010092>
- [35] Boccardo F, Valenzano M, Costantini S, et al. LYMPHA technique to prevent secondary lower limb lymphedema. *Ann Surg Oncol*. 2016; 23(11): 3558–3563. <https://doi.org/10.1245/s10434-016-5282-4>
- [36] Agarwal, S, Garza, RM, Chang, DW. Lymphatic microsurgical preventive healing approach (LYMPHA) for the prevention of secondary lymphedema. *Breast J*. 2020; 26(4): 721–724. <https://doi.org/10.1111/tbj.13667>
- [37] Ward J, King I, Monroy-Iglesias M, et al. A meta-analysis of the efficacy of VLNT in reducing limb volume and cellulitis episodes in patients with cancer treatment-related lymphoedema. *Eur J Cancer*. 2021; 151: 233–244. <https://doi.org/10.1016/j.ejca.2021.02.043>
- [38] Pak CS, Suh HP, Kwon JG, et al. Lymph node to vein anastomosis for lower extremity lymphedema. *J Plast Reconstr Aesthet Surg*. 2021; 74(9): 2059–2067. <https://doi.org/10.1016/j.bjps.2021.01.005>
- [39] Bailey EA, Pandey SK, Chen WF. Advances in surgical lymphedema management: the emergence and refinement of lymph node-to-vein anastomosis. *Curr Surg Rep*. 2024; 12: 83–88. <https://doi.org/10.1007/s40137-024-00395-y>