Journal of Plastic, Reconstructive & Aesthetic Surgery (2019) 72, 1304–1315

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

A reconstructive algorithm after thigh soft tissue sarcoma resection including predictors of free flap reconstruction☆

Sarah M. Elswick[a], Peter Wu[a], Arya A. Arkhavan[b], Vanessa E. Molinar[a], Anita T. Mohan[a], Frank H. Sim[c], Jorys Martinez-Jorge[a,*], Michel Saint-Cyr[a]

[a] *Division of Plastic Surgery, Mayo Clinic, 200 First St SW, Rochester, MN 55905, United States*
[b] *Mayo Clinic School of Medicine, 200 First St SW, Rochester, MN 55905, United States*
[c] *Department of Orthopedic Surgery, Mayo Clinic, 200 First St SW, Rochester, MN 55905, United States*

Received 19 August 2018; accepted 27 April 2019

KEYWORDS
Sarcoma;
Radiation;
Lower extremity;
Reconstruction;
Flap;
Free flap

Summary *Background:* Reconstruction of defects of the thigh after oncologic resection plays a vital role in limb salvage. Our goal was to evaluate our institution's experience on thigh sarcomas to develop evidence-based recommendations to guide the reconstructive surgeon, including factors that would predict the need for free flap reconstruction.
Methods: We reviewed all thigh defects requiring plastic surgeon reconstruction following sarcoma resection at our institution from 1997 to 2014. Patient demographics, comorbidities, multimodality therapies, and operative characteristics were analyzed.
Results: There were 159 thigh reconstructions. Reconstruction was achieved by primary closure (15%), skin graft (13%), local fasciocutaneous flap (8%), local muscle flap (31%), regional muscle flap (28%), or free flap (4%). For the proximal third of the thigh, the most common flaps were pedicled thigh muscle and rectus abdominis flaps; for the middle third of the thigh, it was pedicled thigh muscle flaps; and for the distal third, it was pedicled gastrocnemius muscle flaps. Factors shown to be predictive of requiring a free flap included wide defects ($p = 0.03$) and location in the middle third of the thigh ($p = 0.001$).
Conclusion: There are multiple options for reconstructing defects from thigh STS. When primary closure and skin grafts are not an option, most defects can be closed with pedicled local

☆Parts of this article have been presented by Peter Wu, M.D. at the following meetings: Senior Residents Conference, Plastic Surgery the Meeting, October 16–20, 2015, Boston, MA.

* Corresponding author.
E-mail address: MartinezJorge.Jorys@mayo.edu (J. Martinez-Jorge).

https://doi.org/10.1016/j.bjps.2019.04.016

or regional muscle or fasciocutaneous flaps. Free flap reconstruction is rarely required but can be necessary when defects are wide or located in the middle third of the thigh.

Introduction

Soft tissue sarcomas (STS) represent less than 1% of all malignancies.[1] STS occur throughout the body but are most commonly located in the lower extremity and pelvic girdle.[2] A landmark paper by Rosenberg et al. published in 1982 compared combined-modality treatment with surgery, radiation, and chemotherapy to amputation and found no difference in disease-free or overall survival.[3] Since then, numerous studies have evaluated the use of chemotherapy and have found conflicting results. Hence, the current treatment of choice for STS is wide local excision, preferably limb-sparing surgery (LSS), typically in conjunction with radiation.[4] There are numerous studies evaluating adjuvant therapies, specifically the type and timing of radiation and chemotherapy and their association with postoperative complications, but there is relatively little information regarding the reconstructive process.

Successful reconstruction is vital to LSS, and plastic surgeons play an essential role in this effort by making resection of large tumors or resection of tumors involving vital structures possible. Previous studies have discussed the various types of reconstruction for thigh sarcoma; however, the patients in these studies represent specific populations, do not necessarily separately address the thigh, and the details of flaps utilized in these patients are not provided in most studies.[5-9] Thus, beyond clinical reasoning, there are relatively few guidelines for the reconstruction of thigh STS defects. Our objective was to examine reconstruction options after thigh STS reconstruction to provide the plastic surgeon with an algorithm for reconstructing these challenging defects based on common factors that impact reconstructive options, including specific flaps that can be utilized based on the location of the defect.

Patients and methods

After institutional review board approval through our institution (IRBs 14-000291 and 17-003943), a retrospective review of the electronic medical records of all thigh STS defects managed by 20 surgeons in the Division of Plastic Surgery at Mayo Clinic, Rochester, from 1997 to 2014 was conducted. Patient age, gender, comorbidities, utilization of chemotherapy and/or radiation, wound characteristics (including location, size, and exposure of critical structures), and reconstructive procedure were analyzed.

The wounds were categorized by anatomical location into anterior, posterior, medial, or lateral thigh and subdivided into proximal, middle, or distal third. When defects spanned two or more areas, the wounds were classified by the location of the majority of the defects. Reconstructive procedures were categorized into six groups: primary closure, STSG, local fasciocutaneous flaps, local muscle flaps, regional muscle flaps, and free flaps. Local flaps were defined as flaps utilizing only thigh tissue, whereas regional flaps involved tissue outside of the thigh (including trunk and leg tissue). Some muscle flaps, for example, rectus abdominis muscle flaps, did include an overlying skin paddle. If more than one reconstructive modality was required, the most complex modality was defined as the primary modality; for example, if both an STSG and a regional muscle flap were used, the muscle flap was considered the primary reconstructive modality.

Descriptive statistics were reported as number (percent) for discrete variables and as mean for continuous variables. The associations of patient and defect characteristics with use of free flap reconstruction (versus any other reconstruction) were examined using Fisher's exact test for discrete variables and a Wilcoxon rank sum test for continuous variables. The alpha-level was set at 0.05 for statistical significance. This study adhered to the STROBE guidelines.

Results

Patient characteristics

A total of 159 patients were identified during the study period, with a mean age of 57.2 years (range 14–94) and a mean BMI of 28.9 kg/m^2. Fifty-three percent were male, and 47% were female. The patients had a wide variety of medical comorbidities. Forty-eight patients (30%) were current or former tobacco users. Eighty-seven percent of patients had radiation, mostly in the preoperative and/or intraoperative setting. Forty-two percent of patients received chemotherapy, mostly done in the preoperative setting.

Cancer characteristics

There were 116 patients (73%) who presented with newly diagnosed STS and 43 patients (27%) with previously excised STS. The mean tumor dimension was $9.9 \times 6.9 \times 4.8$ cm, and the majority of tumors were stage III. There were a wide variety of histologic types, the most common being malignant fibrous histiocytoma, liposarcoma, and synovial sarcoma. The tumors were distributed fairly equally throughout the thigh but were most commonly located proximally and medially.

Operative characteristics

Patients underwent both immediate ($n = 136$, 86%) and delayed ($n = 23$, 15%) reconstruction. The primary reconstructive modality included 24 primary closures (15%), 20 skin grafts (13%), 13 local fasciocutaneous flap (8%), 50

Table 1 Wound characteristics and type of reconstruction after thigh soft tissue sarcoma resection.

	Number	Primary closure	STSG	Local fasciocutaneous flap	Local muscle flap	Regional muscle flap	Free flap
Width of defect (cm)							
1-5	22 (16.8%)	5 (22.7%)	2 (9.1%)	0 (0%)	8 (36.4%)	7 (31.8%)	0 (0%)
5.1-10	56 (42.7%)	10 (17.9%)	9 (16.1%)	5 (8.9%)	14 (25.0%)	15 (26.8%)	3 (5.4%)
10.1-15	32 (24.4%)	2 (6.3%)	2 (6.3%)	4 (12.5%)	9 (28.1%)	12 (37.5%)	3 (9.4%)
15.1-20	19 (14.5%)	2 (10.5%)	3 (15.8%)	4 (21.1%)	4 (21.1%)	5 (26.3%)	1 (5.3%)
>20	2 (1.5%)	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	0 (0%)
Not available	28	5	4	0	8	11	0
Surface area of defect (cm^2)							
0-100	39 (29.8%)	6 (15.4%)	7 (17.9%)	0 (0%)	13 (33.3%)	13 (33.3%)	0 (0%)
100.1-200	37 (28.2%)	7 (18.9%)	4 (10.8%)	4 (10.8%)	10 (27.0%)	9 (24.3%)	3 (8.1%)
200.1-300	23 (17.6%)	4 (17.4%)	2 (8.7%)	3 (13.0%)	4 (17.4%)	7 (30.4%)	3 (13.0%)
300.1-400	11 (8.4%)	0 (0%)	1 (9.1%)	3 (27.3%)	2 (18.2%)	4 (36.4%)	1 (9.1%)
400.1-500	8 (6.1%)	0 (0%)	1 (12.5%)	2 (25.0%)	3 (37.5%)	2 (25.0%)	0 (0%)
>500	13 (9.9%)	2 (15.4%)	1 (7.7%)	1 (7.7%)	5 (38.5%)	4 (30.8%)	0 (0%)
Not available	28	5	4	0	8	11	0
Structure exposed							
None	59 (37.1%)	13 (22.0%)	18 (30.5%)	7 (11.9%)	7 (11.9%)	11 (18.6%)	3 (5.1%)
Any critical structure	100 (62.9%)	11 (11.0%)	2 (2.0%)	6 (6.0%)	38 (38.0%)	39 (39.0%)	4 (4.0%)
Major blood vessel	24 (15.1%)	3 (12.5%)	0 (0%)	1 (4.2%)	13 (54.2%)	7 (29.2%)	0 (0%)
Major nerve	12 (7.5%)	2 (16.7%)	1 (8.3%)	0 (0%)	5 (41.7%)	3 (25.0%)	1 (8.3%)
Bone or joint	22 (13.8%)	1 (4.5%)	1 (4.5%)	1 (4.5%)	4 (18.2%)	15 (68.2%)	0 (0%)
Blood vessel and nerve	20 (12.6%)	4 (20.0%)	0 (0%)	2 (10.0%)	8 (40.0%)	4 (20.0%)	2 (10.0%)
Blood vessel and bone	5 (3.1%)	0 (0%)	0 (0%)	1 (20.0%)	4 (80.0%)	0 (0%)	0 (0%)
Nerve and Bone	6 (3.8%)	1 (16.7%)	0 (0%)	0 (0%)	1 (16.7%)	4 (66.7%)	0 (0%)
Blood vessel, nerve, and bone	11 (6.9%)	0 (0%)	0 (0%)	1 (9.1%)	3 (27.3%)	6 (54.5%)	1 (9.1%)
Radiation							
Radiation	138 (86.8%)	17 (12.3%)	14 (10.1%)	12 (8.7%)	41 (29.7%)	47 (34.1%)	7 (5.1%)
No radiation	21 (13.2%)	7 (33.3%)	6 (28.6%)	1 (4.8%)	4 (19.0%)	3 (14.3%)	0 (0%)

local muscle flaps (31%), 45 regional muscle flaps (28%), and seven free flaps (4%). Fourteen patients had multiple reconstructive techniques utilized: 10 patients had an STSG in conjunction with another flap, two patients had a muscle flap (one local and one regional) with a local fasciocutaneous flap, and two patients had both local and regional muscle flaps. One patient had a functional muscle reconstruction for leg extension with excellent results.

The mean defect size was 15.5 long, 9.1 cm wide, and 5.6 cm deep (area of 230 cm^2 and volume of 1681 cm^3). The smallest defect volume was 7.5 cm^3 and the largest was 10,962 cm^3. Two-thirds of patients had a critical structure exposed, including a major blood vessel, major nerve, bone, or joint. There were not enough patients to perform a statistical analysis to determine whether these factors impacted the type of reconstructive modality performed. However, in general, narrow defects were commonly closed through primary closure or STSG, fasciocutaneous flaps were used to close moderate width defects, and local and regional muscle flaps were used relatively equally in all

Table 2 Type of reconstruction based on defect location after thigh soft tissue sarcoma resection.

	Anterior thigh ($n=44$, 27.7%)	Medial thigh ($n=53$, 33.3%)	Posterior thigh ($n=28$, 17.6%)	Lateral thigh ($n=34$, 21.4%)
Proximal third of thigh (n = 66, 41.5%)	***21***	***27***	***8***	***10***
Free flap	0	0	0	0
Pedicled rectus abdominis/DIEP	6	12	1	2
Pedicled gluteus maximus	0	0	1	0
Pedicled thigh muscle flap	11	7	2	3
Pedicled thigh fasciocutaneous flap	2	3	0	2
STSG	1	0	2	0
Primary closure	1	5	2	3

(*continued on next page*)

Table 2 (*continued*)

	Anterior thigh ($n=44$, 27.7%)	Medial thigh ($n=53$, 33.3%)	Posterior thigh ($n=28$, 17.6%)	Lateral thigh ($n=34$, 21.4%)
Middle third of thigh ($n=44$, 27.7%)	***12***	***11***	***11***	***10***
Free flap	1	3	1	1
Pedicled rectus abdominis	0	1	0	1
Pedicled thigh muscle flap	6	4	4	0
Pedicled thigh fasciocutaneous flap	0	1	0	3
Pedicled gastrocnemius flap	0	0	3	0
STSG	2	2	2	2
Primary closure	3	0	1	3
Distal third of thigh ($n=49$, 40.8%)	***11***	***15***	***9***	***14***
Free flap	0	0	1	0
Pedicled gastrocnemius flap	4	7	4	8
Pedicled thigh muscle flap	2	4	2	0
Pedicled thigh fasciocutaneous flap	0	2	0	0
STSG	3	2	0	4
Primary closure	2	0	2	2

widths of defects. The same pattern holds true for the surface area of the defects. If a critical structure was exposed, the reconstructive modality was more likely to be a local or regional muscle flap. Radiated wounds were more often reconstructed with fasciocutaneous, muscle, or free flaps, whereas nonradiated wounds were more likely to be reconstructed with primary closure or STSG with no free flaps performed in nonradiated wounds (Table 1). The type of reconstruction also depended on the location of the defect (Table 2).

Reconstruction of proximal thigh defects

For the anterior thigh, pedicled rectus abdominis/deep inferior epigastric perforator (DIEP) and thigh muscle flaps (rectus femoris, gracilis, sartorius, and vastus lateralis) were most frequently utilized (Figure 1). A fasciocutaneous pedicled flap was used for two cases (anterolateral thigh (ALT) and a perforator flap). For the medial thigh, pedicled rectus abdominis and thigh muscle flaps (gracilis, sartorius, and adductor brevis) were most frequently utilized. A fasciocutaneous pedicled flap was used for three cases (all ALTs). For the posterior thigh, various reconstructive modalities were used equally including pedicled rectus abdominis and gluteus maximus flaps, thigh muscle flaps (biceps femoris), STSGs, and primary closures. For the lateral thigh, pedicled rectus abdominis, thigh muscle flaps (rectus femoris and vastus lateralis), and fasciocutaneous flaps (ALT and keystone) were utilized fairly equally (Figure 2). The most common reconstructive options for proximal thigh defects are summarized in Figure 3.

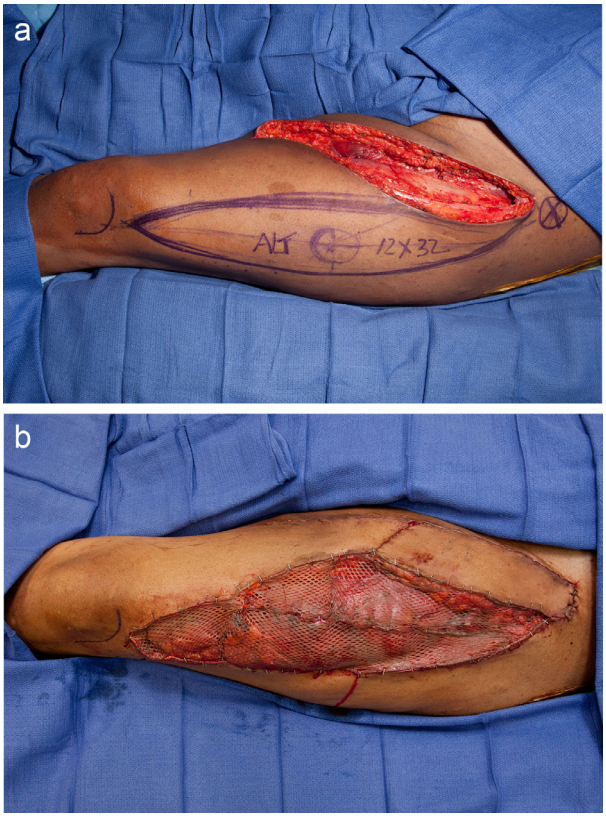

Figure 1 (a) A 32-year-old male with neoadjuvant and intraoperative radiation therapy status post sarcoma excision from the upper anterior thigh (including skin, subcutaneous tissue, and the sartorius muscle) with exposed profunda femoris vessels. (b) The defect was reconstructed using a pedicled anterolateral thigh flap (30 × 10 cm), which was tunneled under the rectus femoris muscle. The distal third of the flap was deepithelized to obliterate dead space. The donor site was then covered with a split-thickness skin graft.

Reconstruction of mid-thigh defects

For the anterior thigh, pedicled thigh muscle flaps (gracilis, sartorius, and tensor fascia lata) were most frequently utilized (Figure 4). One free flap was required (a latissimus dorsi). For the medial thigh, pedicled thigh muscle flaps

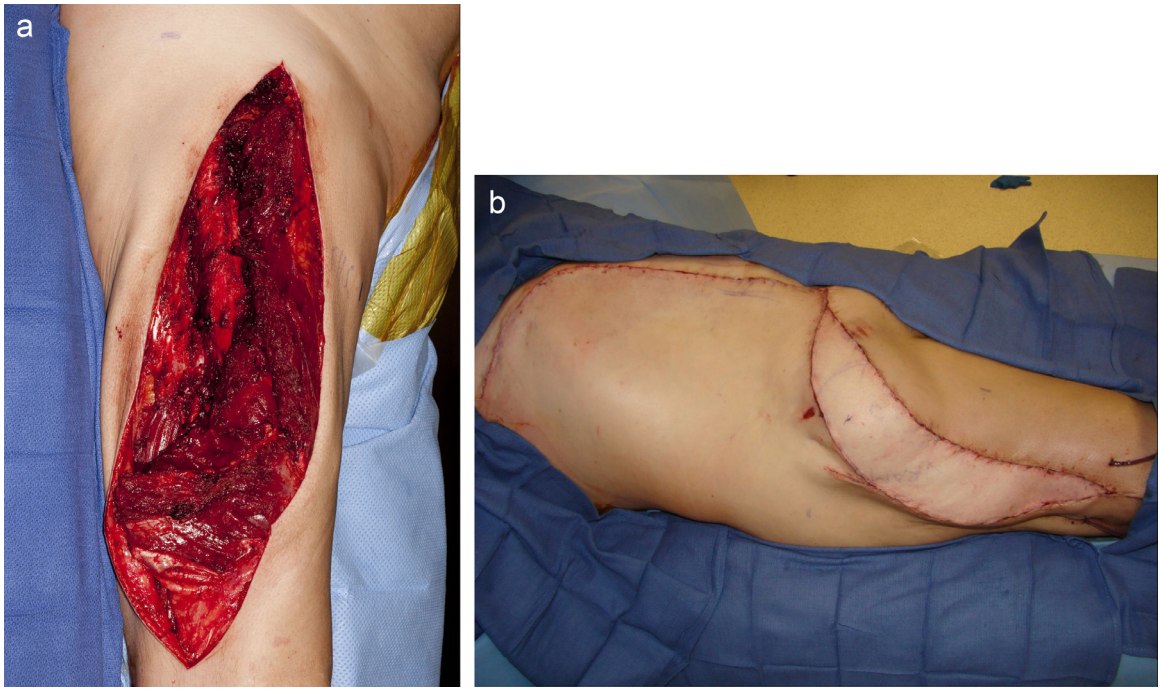

Figure 2 (a) A 64-year-old male with previous inadequate excision of an upper lateral thigh extra-skeletal osteosarcoma and subsequent chemotherapy and radiation now status post re-excision including the skin and subcutaneous tissue with a margin around the previous scar and the vastus lateralis and vastus intermedius muscles with a defect measuring 50 × 16 cm. The defect was reconstructed with an extended VRAM flap. (b) Inset of the flap.

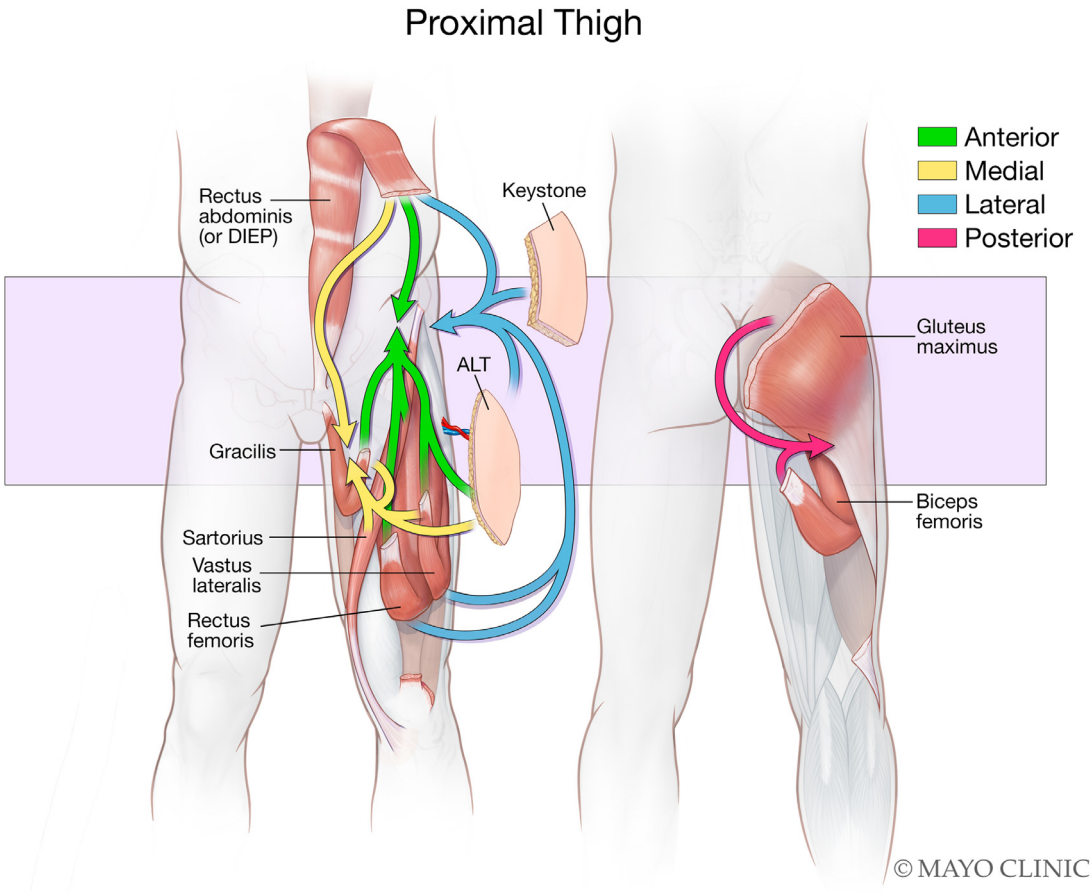

Figure 3 The most common local and regional flap options for proximal thigh defects.

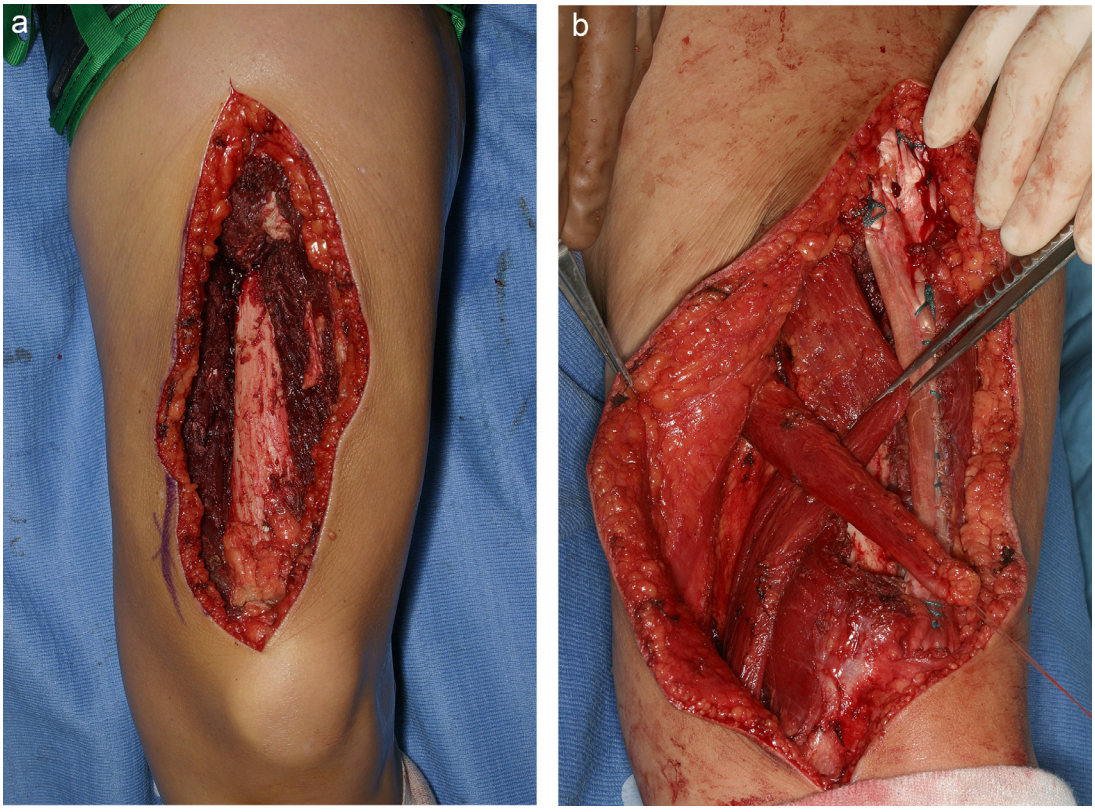

Figure 4 A 22-year-old female with excision of a fibrosarcoma of the middle anterior thigh including the rectus femoris, vastus intermedius, 50% of the vastus medialis, and 10% of the vastus lateralis muscles. The extensor tendon was reconstructed utilizing an Achilles tendon allograft, which was sutured to the stump of the quadriceps tendon distally, the proximal stump of the rectus femoris muscle, the remnant of the vastus lateralis along the length of the tendon allograft, and the transected distal aspect of the gracilis muscle. In addition to the functional pedicled gracilis muscle transfer for leg extension, the defect was reconstructed with a bipedicled sartorius transfer to cover the exposed femur. The skin was closed primarily over the reconstruction.

(adductor longus, vastus medialis, gracilis, sartorius, and rectus femoris) were most frequently utilized. There was one pedicled rectus abdominis flap, one fasciocutaneous keystone flap, and three free flaps (transverse and vertical rectus abdominis muscle flaps). Of note, the middle third of the medial thigh is where the most free flaps were required. For the posterior thigh, pedicled thigh (semimembranosus) and gastrocnemius muscle flaps were frequently utilized. A free VRAM was required in one case. For the lateral thigh, fasciocutaneous flaps [ALT, keystone (Figure 5) and perforator flaps] were commonly used. There was also one pedicled rectus abdominis flap and one free ALT flap. The most common reconstructive options for mid-thigh defects are summarized in Figure 6.

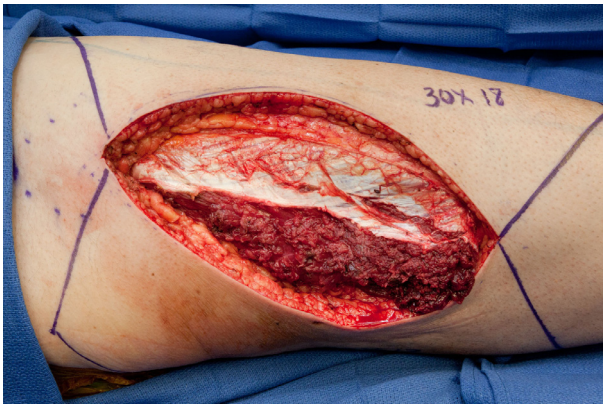

Figure 5 A 52-year-old male with an inadvertently excised sarcoma in the middle lateral thigh status post radiation and re-excision at our institution (defect size 30 × 20 × 17 cm). The defect was reconstructed with double keystone flaps (40 × 25 cm and 40 × 20 cm) with a split-thickness skin graft for closure of the lateral donor site (20 × 10 cm).

Reconstruction of distal thigh defects

For the anterior thigh, pedicled gastrocnemius and thigh muscle flaps (gracilis and sartorius) were most frequently utilized (Figure 7). For the medial thigh, pedicled gastrocnemius and thigh muscle flaps (gracilis) were most frequently utilized. There were also two fasciocutaneous flaps utilized [a keystone flap and a superior genicular artery flap (Figure 8)]. For the posterior thigh, pedicled gastrocnemius and thigh muscle flaps (biceps femoris) were most frequently utilized. One free latissimus dorsi was also utilized. For the lateral thigh, the pedicled gastrocnemius flap was most frequently utilized. The most common

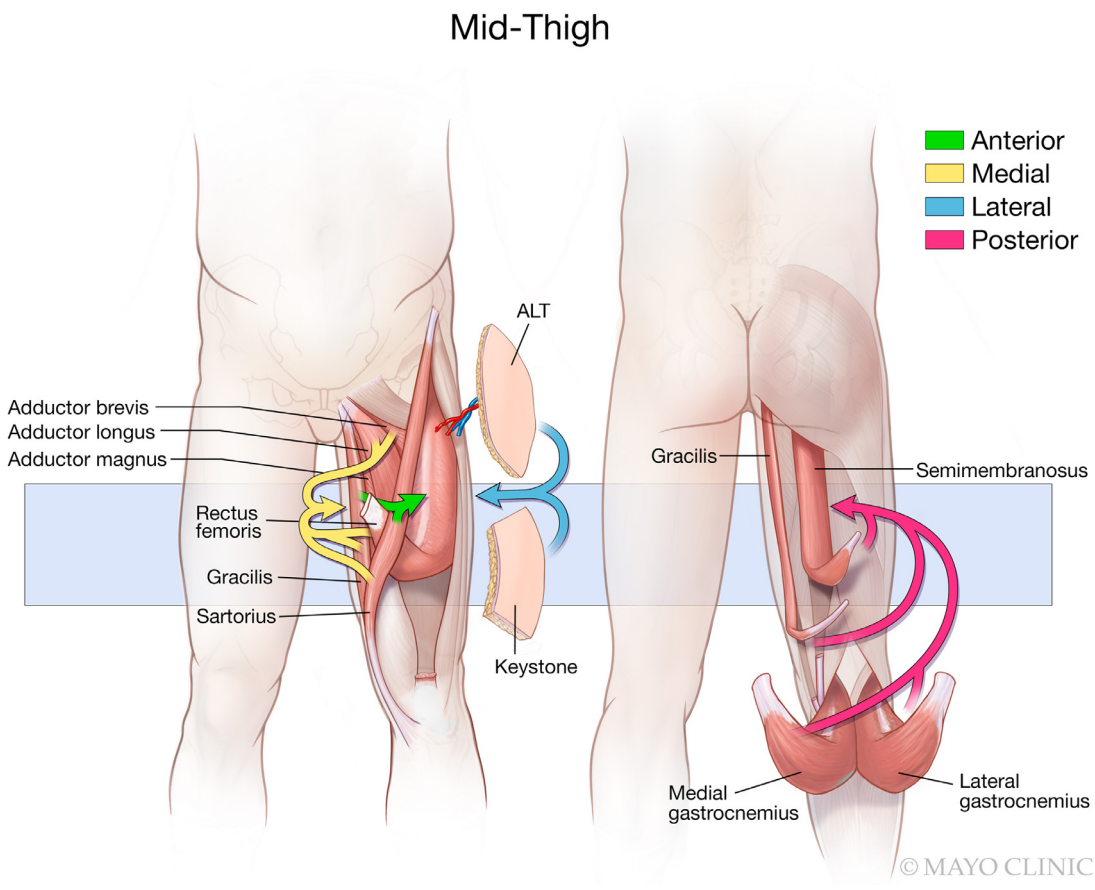

Figure 6 The most common local and regional flap options for mid-thigh defects.

reconstructive options for proximal thigh defects are summarized in Figure 9.

Predictors of free flap reconstruction

Given the abundance of local and regional tissue available in and around the thigh, it was of particular interest to our group to analyze factors that would predict the use of a free flap for reconstruction after thigh STS resection (Table 3). 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 ($p = 0.001$). Patient age, gender, BMI, comorbidities, radiation, chemotherapy, tumor histology, re-excision, area of the defect,

Table 3 Predictive factors for a free flap after thigh soft tissue sarcoma resection.

	Free flap ($n = 7$)	All other types of reconstruction ($n = 152$)	*P* value
Patient characteristics			
Age (years, mean)	55.9	57.3	0.67
BMI (mean)	26.1	27.3	0.44
Gender			0.45
Male	5 (71.4%)	80 (52.6%)	
Female	2 (28.6%)	72 (47.4%)	
Any medical comorbidities	4 (57.1%)	96 (63.2%)	0.71
Any radiation	7 (100.0%)	131 (86.2%)	0.59
Any chemotherapy	3 (42.9%)	64 (42.1%)	1.00
Tumor histology			0.69
Malignant fibrous histiocytoma	0	41 (27.0%)	
Liposarcoma	2 (28.6%)	25 (16.4%)	
Synovial sarcoma	1 (14.3%)	10 (6.6%)	
Rhabdomyosarcoma	0	3 (2.0%)	

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Table 3 (*continued*)

	Free flap ($n=7$)	All other types of reconstruction ($n=152$)	*P* value
Osteosarcoma	0	3 (2.0%)	
Angiosarcoma	0	2 (1.3%)	
Chondrosarcoma	0	5 (3.3%)	
Dermatofibrosarcoma protuberans	0	2 (1.3%)	
Other	4 (57.1%)	61 (40.1%)	
Re-excision	3 (42.9%)	40 (26.3%)	0.39
Size of defect			
Length (cm, mean)	18.6	15.3	0.35
Width (cm, mean)	13.6	8.9	**0.03**
Area (cm^2, mean)	240.4	229.0	0.30
Location of defect (vertical)			**0.001**
Proximal third	0 (0.0%)	66 (43.4%)	
Middle third	6 (85.7%)	38 (25.0%)	
Distal third	1 (14.3%)	48 (31.6%)	
Location of defect (horizontal)			0.79
Anterior	1 (14.3%)	43 (28.3%)	
Medial	2 (28.6%)	26 (17.1%)	
Posterior	3 (42.9%)	50 (32.9%)	
Lateral	1 (14.3%)	33 (21.7%)	
Exposed structures			
Major blood vessel	3 (42.9%)	57 (37.5%)	1.00
Major nerve	4 (57.1%)	45 (29.6%)	0.20
Bone or joint	1 (14.3%)	43 (28.3%)	0.67
None	3 (42.9%)	56 (36.8%)	0.71

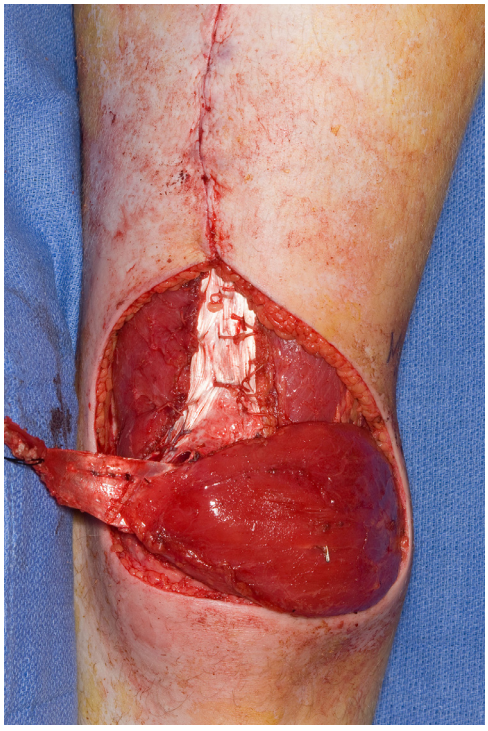

Figure 7 A 21-year-old male with excision of an epitheloid sarcoma of the lower anterior thigh requiring allograft extension mechanism reconstruction. The defect was reconstructed with a pedicled lateral gastrocnemius muscle flap, which was covered with a split-thickness skin graft.

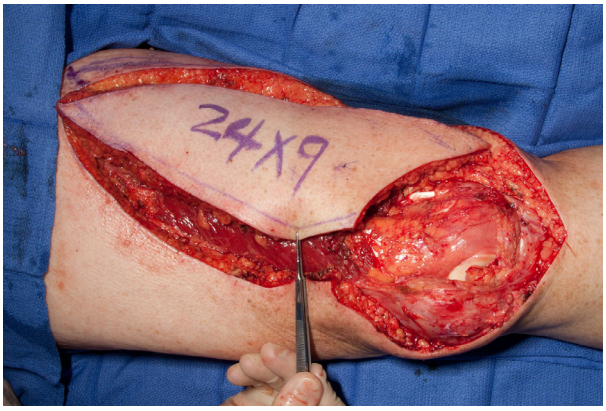

Figure 8 A 75-year-old female with an inadvertently excised myxofibrosarcoma in the lower medial thigh who underwent adjuvant radiation and re-excision at our institution. A perforator flap was designed based off the superior medial genicular artery. A split-thickness skin graft was required to close the donor site (3×2 cm).

circumferential location of the defect, and exposed structures were not found to impact the use of a free flap.

Postoperative outcomes

There were no significant differences in complications, including surgical site infection, wound dehiscence, seroma,

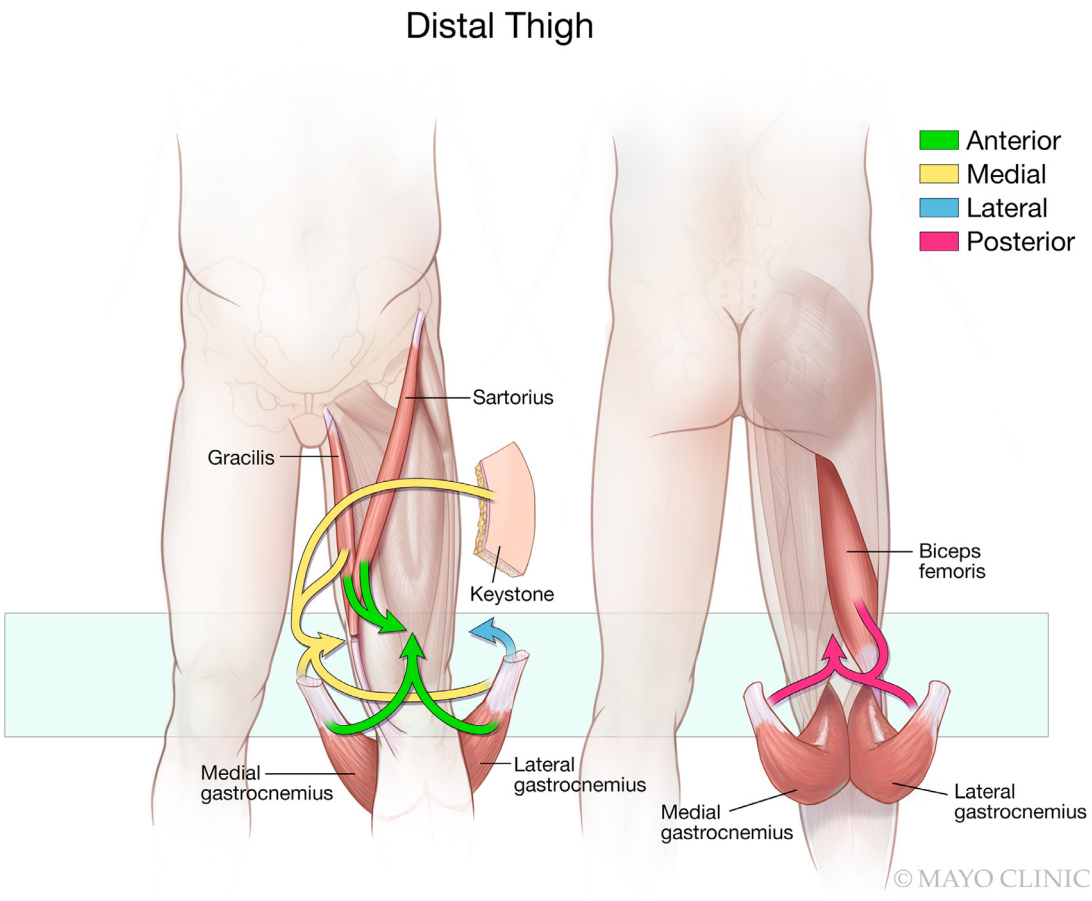

Figure 9 The most common local and regional flap options for distal thigh defects.

hematoma, partial or total flap loss, deep venous thrombosis, and acute limb ischemia, between the various types of reconstruction. The rate of complications was 28.6% in free flaps, 18.5% in pedicled flaps, and 6.8% in skin grafts and primary closure ($p = 0.08$). There were 23 deaths attributable to sarcoma (14.4%).

Reconstructive algorithm

With the above information, we developed a reconstructive algorithm after thigh STS resection (Figure 10). If the wound is able to be closed without tension, then primary closure should be performed. If this is not possible and there are no critical structures exposed, then a skin graft should be placed. Otherwise, one should evaluate whether there is any local or regional tissue available. One can also consider keystone and perforator flaps in all areas of the thigh; these flaps, especially keystone flaps, have become increasingly utilized for thigh STS reconstruction in recent years. Functional reconstructions can also be considered when and where appropriate.

Discussion

LSS is the standard of care for lower extremity STS, as amputation does not impact survival. Advances in surgical technique, radiation technology, and chemotherapy have helped make LSS an even more viable treatment option. Hence, it is of the utmost importance to provide patients with the best reconstructive option. Many publications have assessed the outcomes after surgery for STS in the extremities, but few have specifically addressed how to reconstruct the thigh after STS resection. We present one of the largest such cohort of patients who have undergone reconstruction after thigh STS resection by a plastic surgeon.

Our study showed several trends for reconstruction. Narrow or small surface area defects were commonly closed by primary closure or STSG, fasciocutaneous flaps were used to close moderate width or surface area defects, and local and regional muscle flaps were used relatively equally in all widths and surface area defects. If a critical structure was exposed, the reconstructive modality was more likely to be a local or regional muscle flap. Radiated wounds were more often reconstructed with fasciocutaneous, muscle, or free flaps, whereas nonradiated wounds were more likely to be reconstructed with primary closure or STSG with no free flaps in nonradiated wounds. Only one patient in our cohort underwent a functional reconstruction. The relative infrequent use of functional reconstructions is likely due to two factors. First, there are many muscles in the thigh with synergistic actions; hence, a functional reconstruction is typically not required. Second, we generally do not perform soft tissue reconstruction at the same time as functional reconstruction.

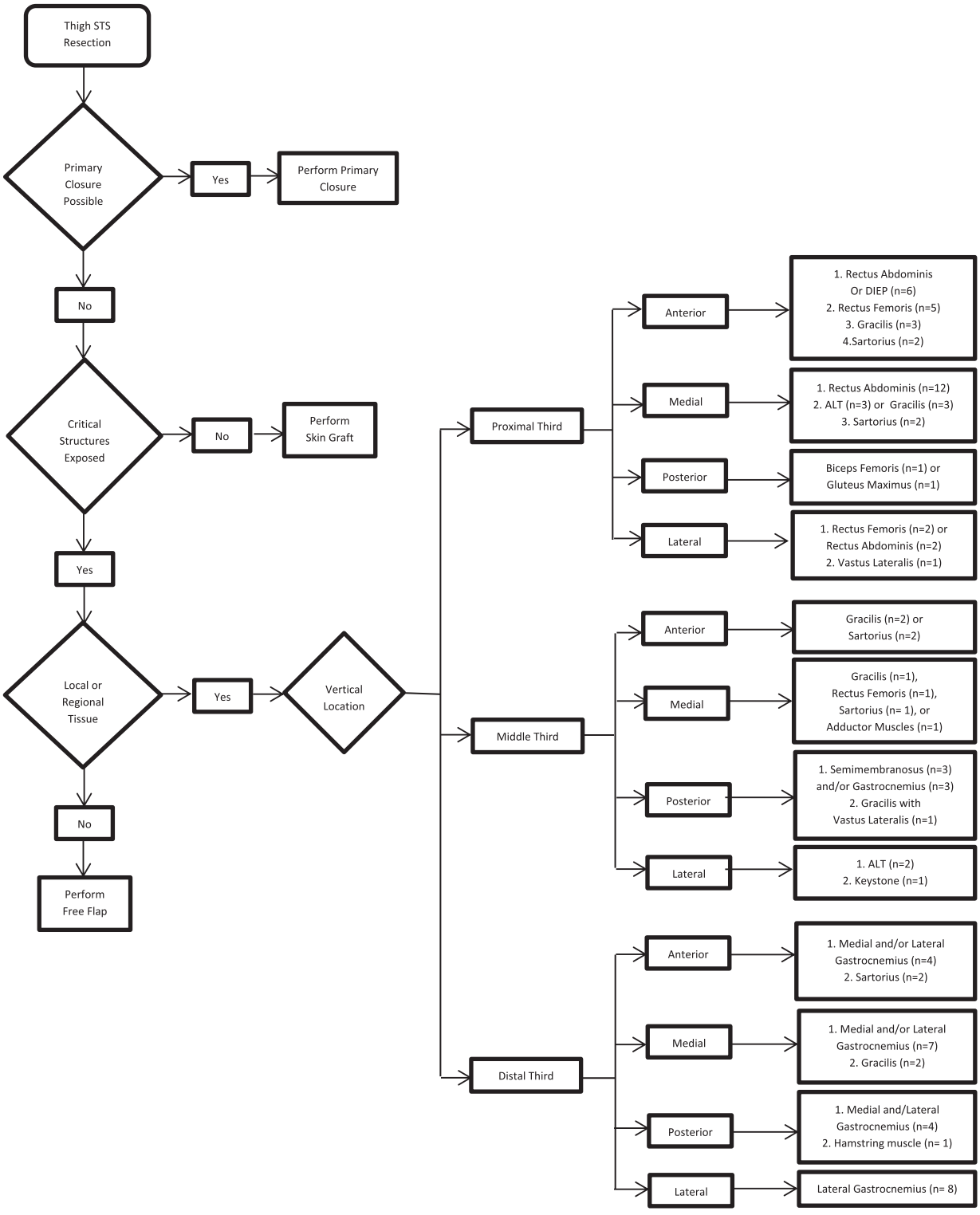

Figure 10 Reconstructive algorithm after thigh STS resection.

By analyzing the various reconstructive modalities, we were able to develop a reconstructive algorithm for patients undergoing thigh STS resection. We found that pedicled flaps were utilized most commonly. For the proximal third of the thigh, in the anterior, medial, and lateral portions, the go-to flaps are the rectus abdominis muscle, rectus femoris muscle, vastus lateralis muscle, and ALT. For the posterior proximal third of the thigh, the go-to flap is the biceps femoris muscle. For the middle third of the thigh, in the anterior, medial, and lateral portions, the go-to flaps are the gracilis muscle, sartorius muscle, rectus femoris muscle, and ALT. For the posterior middle third of the thigh,

the go-to flaps are the semimembranosus or gastrocnemius muscles. For the distal third of the thigh, the go-to flap is the gastrocnemius muscle regardless of the circumferential location of the defect.

Various studies have discussed the reconstructive options after lower extremity STS resection; however, none of these studies specifically address the thigh, and the results are highly variable given the variety in study populations.[5-7,10] Our results show a predominance of local and regional flaps, which is not surprising given the abundance of soft tissue that is available within the thigh and surrounding trunk and leg. The relatively low number of primary closures is likely due to the fact that we included only those wounds that required reconstruction by a plastic surgeon, and many times, the oncologic surgeon managed these reconstructions. A retrospective review from MD Anderson found that plastic surgery reconstruction was required in only 20% of all patients and was more frequently required in the setting of preoperative radiation.[5] López et al. found that free flaps were used more frequently in the lower extremities than in other parts of the body. Their choice of reconstructive modality depended on defect size and exposure of critical structures or orthopedic hardware with a preference for muscular coverage for prosthetic material coverage owing to its superior vascularity and potentially high volume.[11] Muramatsu et al. proposed an algorithm for pedicled and free flap reconstruction depending first on whether the primary goal was wound closure or functional muscle transfer and second on patient positioning.[12] A case-control study by Kang et al. compared flap reconstruction (local, regional, and free flaps) to primary closure after extremity STS resection and found a lower functional score, higher wound complication rate, and longer hospital stay but better local control in the flap group. Subgroup analysis of the flap reconstruction group did not show any difference in wound complication rate based on the type of flap performed.[13]

Free flaps can be challenging after thigh STS resection, as the resections are large and may sacrifice potential recipient vessels in the area. However, they may be necessary if pedicled flaps are unable to reach the defect; there is not enough local or regional tissue available, especially to cover neurovascular structures, bone stripped off its periosteum, or exposed hardware, or when the local tissue has been damaged by radiation. This study showed that wide defects and location in the middle third of the thigh are predictive factors for free flap reconstruction.

One of the first publications to discuss free tissue transfer for reconstruction of the lower extremity after oncologic resection was written by Cordeiro et al. in 1993 and demonstrated an overall success rate of 97%.[14] Similar studies have demonstrated flap survival rates of 89–100%.[6,10,15-17] Townley et al. demonstrated that free flaps could be safely performed in the extremities and trunk after STS resection even with preoperative radiation with no difference in microvascular complications albeit with higher rates of wound healing complications.[18] Another study by Schwartz et al. found lower extremity location and vascular involvement to be risk factors for significant wound complications requiring delayed local or free vascularized tissue transfer.[19] Moreover, Doi et al. and Ihara et al. have both demonstrated success with functional free muscle transfer and state this could allow more radical resection without compromising function.[20]

The goal of this study was to provide the plastic surgeon with a foundation for reconstructive options for these complex cases, but a thorough evaluation of patient factors, reconstruction options, surgeon experience, and clinical judgment is essential. Each patient should be approached individually and the decision on the type of reconstruction is very complex and based on multiple factors. The surgeon needs to consider the functional impact of both the resection and the reconstruction. Sacrifice of muscle, whether locally, regionally, or distantly, may have an unfavorable impact on the patient's functional status, and this needs to be taken into consideration when determining the type of reconstruction that will be performed.

The weaknesses of this study include its retrospective nature and patient and tumor heterogeneity. Given the rarity of the disease, in combination with isolating tumors confined to a single anatomical location, patients were included over a wide time range. We acknowledge that options for reconstruction are always being revised and refined, but many of the reconstructive options discussed in this study that form the basis of the armamentarium for thigh reconstruction for the plastic surgeon are well described and can be easily implemented by any reconstructive surgeon. The sample size and number of reconstructive techniques also limited our ability to perform an in-depth statistical comparison of the various reconstructive modalities. In addition, the small number of free flaps makes the complication rate in this subgroup look deceptively high (two patients out of seven had a complication). Further work is needed to refine recommendations for these challenging cases.

Conclusion

Thigh STS defects require the reconstructive surgeon be well versed in the full spectrum of surgical options. We appreciated several trends regarding the choice of reconstructive modality. Pedicled local or regional flaps were most commonly used; for the proximal third of the thigh, it was thigh muscle and rectus abdominis flaps; for the middle third of the thigh, it was thigh muscle flaps; and for the distal third, it was gastrocnemius muscle flaps. Free flaps may be required for wide defects or those located in the middle third of the thigh.

Conflicts of interest

The authors have no financial or personal relationships to declare in relation to the content of this article.

Funding statement

The authors received no specific funding for this article. REDCap database was utilized for data collection and analysis; REDCap at our institution is funded through the Center for Clinical and Translational Science grant support (UL1 TR000135).

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