Management of soft-tissue sarcomas; treatment strategies, staging, and outcomes

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Abstract – Soft-tissue sarcomas (STS) are a rare group of malignant tumors which can affect any age group. For the majority of patients who present with a localized STS, treatment involves a multidisciplinary team decision-making approach ultimately relying on surgical resection with or without adjuvant radiation for successful limb salvage. The goals of treatment are to provide the patient with a functional extremity without local tumor relapse. The purpose of this article is to review the treatment of extremity STS, with a focus on staging, treatment options, and outcomes.

Key words: Soft tissue sarcoma, Outcome, Management, Reconstruction.

Introduction

Soft-tissue sarcomas (STS) are a diverse group of rare malignant tumors which arise from mesenchymal tissue. Approximately 11,000 new cases of STS are diagnosed each year in the United States, accounting for <1% of all cancers [1]. STS can occur over all age ranges, however the median age at diagnosis is 56–65 years, peaking in the 8th decade [2]. STS can arise anywhere in the body, however, the extremities account for 60% of cases, with the thigh being the most common site of disease [2]. STS are classified based on the mature tissue they resemble, with nearly 100 histologic subtypes in the World Health Organization (WHO) classification [3]. These subtypes vary based on molecular characteristics, clinical behavior, and response to treatment. Low-grade tumors may be locally invasive but rarely metastasize. Higher grade tumors exhibit more aggressive behavior and a higher risk of mortality due to the development of metastatic disease (predominantly to the lungs) [4].

Etiology, clinical presentation, and diagnosis

The etiology of most STS remains unknown; however, there are certain environmental factors and genetic predispositions which have been associated with the development of some types of STS, including neurofibromatosis and Li-Fraumeni syndrome. The initial signs and symptoms of a STS may vary depending on the tumor site, subtype, and grade. Most commonly patients present with an enlarging painless mass, however tumor growth can cause pain via a mass effect on nearby neurovascular structures.

Certain tumors have a tendency to appear at a certain age (e.g. liposarcoma in adults and rhabdomyosarcoma in children). Likewise, certain STS are more common in specific anatomic locations: liposarcoma is more common in the lower extremity, whereas synovial sarcoma, epithelioid sarcoma, and fibrosarcoma are encountered more often in the upper extremity [4]. Rapid growth raises concern for a malignant diagnosis, while fluctuations in size can be seen in benign lesions such as ganglion cysts and vascular malformations. A small, soft, superficial, mobile mass is most likely to be benign [5]. Asking the patient to contract the muscle adjacent to the mass and assessing its subsequent mobility can help in defining the relationship of the mass to the underlying fascia.

Diagnosis of a soft-tissue sarcoma

There are three factors which need to be evaluated as part of the investigation of a patient with a STS: (1) local extension,
(2) histological diagnosis, and (3) staging of metastases. Each of these pieces of information plays an important role in developing a patient-specific treatment plan [8, 9].

Assessment of local extension

STS generally spread along tissue planes, compressing the surrounding tissues and typically do not violate anatomic barriers such as fascia or bone. It is unusual for a STS to invade bone, but when it occurs, bone invasion is associated with a significant reduction in overall survival [10]. Likewise the microscopic extent of tumor cells in the edema surrounding a STS, as seen on magnetic resonance imaging (MRI), could represent a cause of local recurrence if left untreated [11].

Imaging evaluation is best performed by MRI of the extremity. Plain radiographs are rarely required but can help identify bone remodeling, bone invasion, and soft-tissue calcification or ossification [12]. MRI is considered the “gold standard” for defining the local extent of the tumor and surrounding edema (Figure 1) [11]. MRI technology can reconstruct a three-dimensional model from cross-sectional images and provides pertinent anatomic information related to the tumor and its proximity to critical neurovascular structures and bone. This information is important for planning surgical excision, as the strongest predictor of local recurrence is a positive surgical margin [13, 14]. The addition of gadolinium contrast to the MRI can help differentiate between cystic areas representing hemorrhage or necrosis based on peripheral

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**Figure 1.** Selected T1 (A) and fat-saturated T2 (B) axial as well as fat-saturated coronal T2 (C) MRI images of a 60-year-old patient with a large, deep mass located in the anterior thigh. On the pretreatment imaging the mass was intimately associated with the femoral neurovascular bundle (arrow) as well as the periosteum of the femur (star). A biopsy was performed and showed high-grade pleomorphic rhabdomyosarcoma. The mass measured approximately 27 cm cranial/caudal however was associated with peritumoral edema which spanned nearly the entire length of the femur on coronal fat-saturated T2 (D) MRI images.
Histological diagnosis

Pathological assessment is necessary to define the histologic subtype and grade and should be obtained prior to definitive treatment if there is concern for a STS. Different subtypes can vary in their clinical behavior and response to treatment and histologic grade has been identified as one of the strongest predictors of metastatic risk and disease-free survival [14, 16–19].

In the case of a suspected STS, biopsy should be performed prior to excision in order to avoid inadequate surgery. Two types of biopsies are commonly used today: needle (fine-needle aspiration (FNA), core needle biopsy (CNB)) and open biopsy (incisional, excisional). Needle biopsies are less time consuming, relatively inexpensive, cause minimal morbidity, limited soft-tissue contamination, and can be performed in an outpatient clinic setting [20–23]. FNA may be able to establish the presence of malignancy, but CNB is usually required as it provides the pathologist with an adequate tissue sample, and it has been suggested that 4–6 cores of tumor tissue are necessary for an accurate diagnosis [24].

Incisional biopsy provides a larger amount of tissue for histologic assessment and grading and thereby provides a better estimate of prognosis [24]. An operative biopsy should be carefully planned using a longitudinal/extensile incision that can be excised as part of a definitive surgical incision should the final diagnosis confirm a STS. Careful hemostasis is critical to minimize the risk of soft-tissue contamination by hematoma. Excisional biopsy of an extremity mass without a definitive diagnosis is usually reserved for small, superficial, and mobile masses which are most likely to be benign, or situations in which the diagnosis is in doubt but excision can be easily performed with a true wide margin.

Staging

The diagnostic workup is completed by staging investigations for regional and distant metastases. The two most commonly used staging systems are the American Joint Committee on Cancer (AJCC) staging system and the Musculoskeletal Tumor Society (MSTS) staging system [25]. Both of these staging systems utilize the local extent of the tumor (size and depth for AJCC vs. compartment status for MSTS), histologic grade, and the presence or absence of metastases.

Extremity STS most commonly metastasize hematogenously with a strong predilection for the lungs and 10% of patients will have detectable pulmonary disease at the time of initial presentation [26]. The initial workup should include systemic staging by chest computed tomography (CT)-scan to evaluate the lungs. A bone scan can be used to evaluate for the rare occurrence of metastatic bone disease although it can be negative even in the presence of osseous metastases. In addition to a bone scan, a positron emission tomography (PET) scan can be helpful in staging of recurrent disease. If the biopsy confirms the diagnosis of a subtype of STS prone to metastasize to lymph nodes, imaging of the regional lymph nodes with a CT scan should be undertaken.

Treatment of extremity soft-tissue sarcomas

Every patient with a soft-tissue sarcoma in the upper or lower extremity will require an individualized treatment plan. Various patient, tumor, and anatomic characteristics need to be evaluated in a multidisciplinary setting in order to generate the optimal treatment plan.

Most localized extremity STS are best treated surgically with or without radiation therapy. Chemotherapy is usually reserved for management of patients with metastatic disease either at presentation or following resection of the primary tumor, or less commonly for attempting to facilitate local tumor down-staging for very extensive lesions which might not otherwise be amenable to limb sparing surgery. Isolated lymph node metastases are somewhat of an exception however as long-term survival is still possible following surgical resection [7]. The overall treatment goal is to achieve maximal oncologic control and render the least functional impairment. As is the case in all areas of medicine, a thoughtful “risks-benefits” discussion is critical and each patient should be involved in the multidisciplinary decision-making process.

The term “oncologic control” refers to minimizing each patient’s risk of local and systemic recurrence with current treatment modalities. Historically, many soft-tissue sarcomas of the extremity were treated with amputation or radical resection alone. Although this approach provided a high degree of local tumor control, it was at the expense of residual limb function and yet still left patients at risk for developing metastatic disease. The introduction of adjuvant radiotherapy and developments in cross-sectional imaging, particularly MRI, has allowed more conservative resection margins to be considered safe, thereby extending the indications for limb salvage. In general, modern limb-salvage techniques can achieve comparable oncologic control with superior functional outcomes compared to amputation. As a result, primary amputation for management of extremity STS is rarely indicated except for situations with very extensive and locally invasive disease (Table 1) [27].

Radiation therapy is recommended for all STS where surgery will provide less than a wide negative resection margin. Adjuvant radiation can be given preoperatively or postoperatively and this was the subject of a randomized clinical trial (RCT) [28]. Preoperative radiation typically prescribes a total of 50 Gy delivered in 2 Gy daily fractions over five weeks followed by surgery four to six weeks after the completion of radiation. In comparison, postoperative radiation begins approximately four to six weeks after surgery or once the wound has adequately healed, and typically involves
30–33 daily fractions delivered over six weeks to a total of 60–66 Gy. Preoperatively the radiation field encompasses the tumor and an additional surrounding region to account for tissues that may have microscopic disease. Postoperatively a larger dose of radiation is given to a larger target volume because of the theoretical issues of tissue hypoxia, and the fact that the entire surgical wound needs to be included in the treatment field. Preoperative radiation is associated with a significantly higher wound complication rate, [28] which can be partially minimized by the timing of surgery [29, 30]. Wound complications following preoperative radiation can complicate patients’ short-term outcome but are usually resolvable and have little impact on long-term function [31, 32]. Long-term follow-up of patients in this randomized trial demonstrated the sequela following postoperative radiation can be permanently disabling [31]. Importantly, there were no differences in local or systemic disease recurrence between patients treated with preoperative or postoperative radiation.

In the above RCT, patients who received 50 Gy preoperatively and had positive resection margins were treated with an additional 16 Gy radiation boost following surgery. Two subsequent studies showed that this postoperative radiation boost increased the total dose of radiation without offering any detectable advantage in local control so this practice has since been abandoned at our institution, as well as many others in North America, but has yet to become a widely accepted treatment policy [33, 34]. In cases with particularly radiosensitive tumors, such as myxoid liposarcoma, preoperative radiation can lead to substantial tumor shrinkage prior to surgery and is associated with excellent outcomes [35–37]. Although preoperative radiation is associated with an increased risk of early wound complications, it does not impede successful microvascular anastomosis in cases needing free flaps for soft-tissue reconstruction, but avoids direct radiation to a free tissue transfer, rotational flap, or skin graft when needed for wound coverage [38].

Surgical margin has an important impact on outcome because it may be the only independent risk factor under the surgeon’s control in the treatment of an extremity STS [14, 40, 41]. Other well-known risk factors such as tumor size, grade, depth, and patient age are considered non-modifiable at disease presentation [14]. The definition of a “safe” surgical margin continues to evolve during the limb-salvage era. There are certain context-specific differences in terms of local oncologic control based on margin status [40, 41]. For superficial STS, or small and deep STS, surgery alone can provide a high degree of local control as long as true wide negative resection margins (i.e. 1–2 cm of surrounding normal tissue or a fascial barrier) can be obtained. Gerrand et al. classified positive margins into low and high-risk groups based on the risk of local recurrence [41]. They found that microscopic positive margins that occurred following planned dissections close to major blood vessels, motor nerves, or bone, in order to spare those critical structures, were associated with low

**Table 1.** Indication for primary amputation for extremity soft tissue sarcomas.

| Indications for amputation [27] |
|-----------------------------|
| 1) Limb salvage would result in inadequate function of the limb. |
| 2) Composite tissue involvement. |
| 3) Prior unplanned excision (resulting in widespread tissue contamination) with exposed multiple neurovascular structures and/or bone. |
| 4) Elderly patients with major medical comorbidities who are unlikely to tolerate a major operation (a potential indication for primary amputation). |

**Figure 2.** Preoperative radiotherapy planning volumes for the patient in Figure 1 are shown on axial (A) and coronal (B) CT images. The Gross Tumor Volume (GTV) is demonstrated by the solid red contour; Clinical Target Volume (CTV) is demonstrated by the green solid contour; Planning Target Volume (PTV) is shown by the blue solid contour; and the thick yellow line represents the prescribed radiotherapy dose volume. Note that intensity-modulated radiotherapy (IMRT) was used to adequately encompass the radiotherapy target volume while avoiding the bone by sculpting the high dose volume around the femoral cortex for protection purposes (A), while also accounting for the peritumoral edema surrounding the lesion (B) which was demonstrated on the coronal fat-saturated T2 post-gadolinium image in Figures 1C and 1D.
rates of local recurrence when combined with radiation therapy. In contrast, an unplanned positive soft-tissue margin or a positive margin obtained following re-excision to salvage an unplanned excision performed elsewhere with positive margins, were both associated with local recurrence rates greater than 30%. Therefore it is best to avoid positive margins in either of these scenarios, if at all possible, in order to achieve a good outcome. In the case of a previously unplanned excision, although there is no association between the detection of sarcoma at the second procedure and the initial size or grade of the tumor, use of preoperative radiation, or the time lapse between interventions, identification of tumor in the re-excision specimen pathologically does significantly increase the risk for local tumor relapse [42]. At our institution we advise wide re-excision if possible for all patients who present following an initial unplanned excision with positive margins.

Other studies have assessed the safety and efficacy of close dissection along bone or critical neurovascular structures to facilitate limb salvage combined with radiation therapy (Figure 3). Clarkson et al. found no difference in local or systemic recurrence rates when epineural dissection was performed for buttock or thigh STS in order to preserve the sciatic nerve [43]. O’Donnell et al. showed that a positive margin following a close dissection to spare a major neurovascular structure or bone is relatively safe in terms of local recurrence, but is associated with worse cause-specific survival [44]. This study also showed that if a nerve or vessel is surrounded by tumor or a bone is invaded, complete resection of that structure en-bloc with the tumor to facilitate negative margins did not improve systemic disease control. Therefore the biology of each tumor plays a critical role in determining the ultimate oncologic outcome for the patient. These results suggest that critical structures can be preserved, in the context

Figure 3. At the time of surgical excision (A), the femoral neurovascular bundle was very close to the tumor (arrow), with multiple perforating blood vessels entering the tumor (B). Due to preoperative IMRT it was safe to create a dissection plane between the tumor and the neurovascular bundle (C). The periosteum was also raised from the femur (pointer) as a margin along the tumor in the region where it was adherent to the bone (D). In the case of a previously unplanned excision, although there is no association between the detection of sarcoma at the second procedure and the initial size or grade of the tumor, use of preoperative radiation, or the time lapse between interventions, identification of tumor in the re-excision specimen pathologically does significantly increase the risk for local tumor relapse [42]. At our institution we advise wide re-excision if possible for all patients who present following an initial unplanned excision with positive margins.

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Tabelle 2. Risikofaktoren für radiationsassoziierte pathologische Femurfraktur.

| Risikofaktoren [48, 50] |
|-------------------------|
| 1) Alter bei Indikationsbeginn |
| 2) Große Tumorsgröße |
| 3) Lokalisation des Tumors (anteriorer Oberschenkelbereich ist am größten Risiko) |
| 4) Grad von Periostabschleifung |
| 5) Geschlecht |
| 6) Postoperative Strahlenbehandlung |
| 7) Hochdosierte Strahlentherapie im Knochen aufgrund von Knochenvermeidungsprinzipiellen |

von multidisziplinärer Behandlung, es sei denn, sie sind nicht invasiv oder komplett von Tumor umgeben sind [43–46]. In Fällen, in denen der Tumor in den Knochen übergeht, ist eine Resektion das Segment von Knochen und die Wiederherstellung des osseären Defektes notwendig, um eine ausreichende chirurgische Grenze zu erhalten und den Gliedmaßenretentionsverlust zu minimieren [10]. Andernfalls bietet eine periostale Grenze ausreichende lokale Kontrolle, wenn kombiniert mit adjuvanten Strahlentherapien (Abbildung 3).

Frakturen im Strahlenschutzbereich können insbesondere problematisch sein, da radiierte Knochen nicht ausreichend heilen können. Frakturen im Strahlenschutzbereich können sich auf den Femur auswirken, und es besteht ein höheres Risiko, dass postoperative Frakturen auftraten, wahrscheinlich aufgrund der Kombination von höherer Strahlendosis und größerem Behandlungsgebiet [47–49]. Hochrisikopatienten können identifiziert werden, indem man die Patienten- und Behandlungsvariablen, die in einem Nomogramm (Tabelle 2) [50] zusammengefasst sind, identifiziert, sowie spezifischen Knochenvermeidungsprinzipien [48]. Patienten, die als Hochrisiko bezeichnet werden, um eine pathologische Fraktur zu entwickeln, hatten einen niedrigeren Follow-up und profitierten von prophylaktischer internen Implantation, entweder während oder nach der Behandlung [50].

Soft-tissue reconstruction

Das primäre Ziel von onkologischen Eingriffen ist die negation von chirurgischen Grenzen, und dies ist oft der Fall, dass große Soft-tissue Defekte nach Resektion nicht zu einer Primärwundversorgung führen [51]. Soft-tissue Wiederherstelung nach einer Resektion einer STS folgt der Theorie der orthoplastischen Wiederherstellung basierend auf der „reconstructive ladder“ wie beschrieben von Levin [52]. Gemäß diesem Protokoll, der Wiederherstellung des Chirurgen verwendet die einfachste Technik, um eine Wunde zu überdecken (z.B. primäre Wundversorgung) und dann nach komplexeren Operationen zu kommen, um eine Wundversorgung und das maximale funktionelle Ergebnis zu erreichen.

Skin grafting

Nach primärer Wundversorgung; Wundversorgung ist der erste Schritt in der Wiederherstellung. Split thickness skin grafting (STSG) kann in einem well-vascularized wound to cover muscle and tendons with paratenon verwendet werden. Ein historischer Kontraindikation zu STSG war ein radiertes Wundbett; jedoch, neueste Studien haben gezeigt, dass ein STSG eine dauerhafte Abdeckung einer radiertes Wundbett und Heilung kann durch eine negative Druckwundversiegelung [33].

Flaps

Wenn die Soft-tissue Defekte nach STS Resektion durch primäre Wundversorgung oder destruktive Wundversorgung geführt werden, können Patienten leiden unter erheblicher physischer und emotionaler Behinderung und reduzieren das Gesundheitszustand (QOL). Um die Auswirkungen dieser Eingriffe zu evaluieren, bei Patienten, verschiedene funktionalen Beurteilungen haben bereits eingesetzt. Die am häufigsten genutzten Outcome-Maßnahmen sind die Toronto Extremity Salvage Score (TESS) und der Musculoskeletal Tumor Society (MSTS) Scoring system [55–57]. Der TESS ist ein Patientenbeobachtungsformular, das bewertet wird und seine Limitationen, während der MSTS-87 ein physikaler Rating basiert auf der Funktionalität von spezifischen anatomischen Lokalisationen (z.B. Hüfte, Knie) während der MSTS-93 ist ein physikaler Rating basiert auf der Funktion des gesamten Extremitätenbereiches (oberer vs. unterer) [55–57].

Resektion von Extremität STS ist häufig ein sehr invasiver Eingriff, der das Leben eines Patienten stark beeinflussen kann, aber bei großen Patienten ist ein moderate-to-high funktioneller Unterschied nach Gliedmaßenretention [32, 58] (Tabelle 4). Prädiktoren für eine funktionelle Auswirkung nach Resektion von STS umfassen eine große Tumorsgröße, hohe Grade von Tumoren, tiefe Tumoren, Resektion von Knochen, und Opfierung eines großen Motorsignals [58, 59]. In der Tat, Patienten, die nicht in der Lage sind, in der Rolle des Follow-up behandelt zu werden, [60] und ihre präoperative Erwartungen [61] können einen signifikanten Einfluss auf den Gesamtstatus haben [55–57].

Surveillance

Die Überwachung der meisten lokalen Rezidive und entweder Lungenmetastasen wird in den ersten zwei Jahren nach Behandlung, als sie erscheinen, hochrisiko-patienten sind in der Follow-up jährlich für die ersten zwei Jahre der klinischen Untersuchung und eine Thorax-Röntgenaufnahme oder CT-Scan. Wir überwachen nur den Oberrand des chirurgischen oder Lymphknoten in der klinischen Untersuchung, wenn es klinische Besorgnisse für lokale oder regionale Rezidive gibt.
Table 3. Common flaps for extremity reconstruction.

| Type of flap          | Free vs. Pedicled | Pedicle            | Indication                                                                 |
|----------------------|-------------------|--------------------|-----------------------------------------------------------------------------|
| Fasciocutaneous flaps|                   |                    |                                                                             |
| Radial Forearm       | Free or Pedicled  | Radial artery antegrade or retrograde | Smaller soft tissue defects, exposed tendons, bone, joints, or neurovascular structures |
| Anterolateral thigh (ALT) | Free or Pedicled | Descending branch lateral femoral circumflex | Large soft-tissue defects, coverage of exposed tendons, bone, joints, and neurovascular structures |
| Muscle flaps         |                   |                    |                                                                             |
| Latissimus dorsi     | Free or Pedicled  | Thoracodorsal      | Large soft-tissue defects with exposed bone, hardware, and neurovascular structures. Functional restoration of the elbow |
| Rectus abdominis (TRAM or VRAM)* | Free or Pedicled | Deep inferior epigastric | Large soft-tissue defects with exposed bone, hardware, and neurovascular structures |
| Gracilis             | Free              | Medial femoral circumflex artery | Medium soft-tissue defects with exposed bone, hardware, and neurovascular structures. Can also be innervated as a functional reconstruction |
| Gastrocnemius        | Pedicled          | Medial or lateral sural artery | Medium soft-tissue defects around the proximal tibia and knee. Functional restoration of the extensor mechanism of the knee |

* TRAM = transverse rectus abdominis myocutaneous flap and VRAM = vertical rectus abdominis myocutaneous flap.

Table 4. Functional outcome following sarcoma resection.

| Paper                  | Patient population | Comparison                          | Outcome measure         | Impact on functional outcome                                                                 |
|------------------------|--------------------|-------------------------------------|-------------------------|------------------------------------------------------------------------------------------------|
| Davis et al. [58]      | Lower extremity STS| Function of patients with limb salvage | MSTS 87, MSTS 93, TESS, SF-36 | Large tumor size: Motor nerve resection (femoral, obturator, sciatic, peroneal, and posterior tibial nerves): Postoperative complications: High-grade tumors: Bone resection: |
|                        |                    |                                     |                         | Lower extremity MSTS 1987, MSTS 1993, TESS Lower MSTS 1987 Lower MSTS 1993 and TESS Lower MSTS 1993 |
| Davis et al. [32]      | Extremity STS       | Pre- vs. Postoperative radiotherapy | MSTS, TESS, SF-36       | Postoperative radiotherapy: SF-36 compared to normative data: Wound complications: Large tumor size (>10 cm): Motor nerve resection: Previous unplanned excision: |
|                        |                    |                                     |                         | Improved MSTS, TESS, and SF-36 at 6 weeks postoperative only Lower for both treatment arms across all time points Lower MSTS at 6 weeks, 3, 6, 12, and 24 months Increased disability compared to baseline TESS Lower MSTS scores at 6, 12, and 24 months Lower MSTS scores Lower TESS score at 3, 6, 12, and 24 months |

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Table 4. (continued)

| Paper                  | Patient population | Comparison | Outcome measure | Impact on functional outcome                                                                                                                                 |
|------------------------|--------------------|------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Davis et al. [31]      | Extremity STS      | Late morbidity:  
- Pre- (50 Gy) vs. (66 Gy) Postoperative radiotherapy | MSTS  
TESS  | Subcutaneous fibrosis:  
- Decreased MSTS and TESS  
Joint stiffness:  
- Decreased MSTS and TESS  
Extremity lymphedema:  
- Decreased MSTS and TESS  
Pre- vs. Postoperative radiotherapy:  
- No difference in MSTS or TESS  
- Trend toward greater fibrosis with postoperative radiotherapy |
| Payne et al. [63]      | Upper extremity STS with flap coverage | Pedicled vs. Free flap for wound coverage | MSTS 87  
MSTS 93  
TESS  | Pedicled vs. free flaps:  
- Decreased MSTS 87 from pre- to postoperative in patients with either pedicled or free flap  
- Decreased MSTS 93 for free flaps  
- No difference in TESS between groups  
- Patients rated their function better compared to the actual rated impairment |
| Davis et al. [66]      | Lower extremity limb salvage sarcoma patients | Relationship of symptoms to function during 1st year postoperative | Stiffness  
Fatigue  
Pain  
Weakness  
Limited range of motion  
TESS  | Stiffness:  
- Plateaus at 3 months  
- Remains constant over the year  
Fatigue:  
- Plateaus at 3 months  
- Remains constant over the year  
Pain:  
- Constant for 3 months then declines over study  
Weakness:  
- Constant for 3 months then declines over study  
Limited Range of Motion:  
- Constant decline over study  
TESS:  
- Presence of pain, stiffness, weakness, and limited range of motion were predictors of worse outcome |
| Gerrand et al. [59]    | Lower Extremity Limb Salvage Sarcoma patients | Sarcoma location and functional outcome:  
- Groin/Femoral triangle  
- Buttock  
- Anterior thigh  
- Medial thigh  
- Posterior thigh  
- Popliteal fossa  
- Posterior calf  
- Anterolateral leg  
- Foot and ankle | MSTS 93  
TESS  | Deep vs. superficial:  
- Superficial tumors have improved MSTS and TESS scores  
Superficial tumors:  
- No decrease in MSTS or TESS from to pre- to postoperative  
Deep Tumors:  
- No difference in MSTS or TESS based on tumor location  
Groin/Femoral triangle tumors:  
- Increased pain based on the MSTS compared to other anatomic areas  
- Decreased ability to sit, put on socks, getting in and out of bath, bending to pick up items  
- More likely to have a limp or gait handicap  
Buttock/Posterior thigh:  
- Decreased ability to sit |

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on physical examination in the clinic or changes noted by the patient. After the first two years high-risk patients are reviewed every six months until five years and then annually until 10 years.

**Summary**

Extremity STS are aggressive and rare malignant tumors with several factors such as size, depth, grade, and tumor location which influence outcome. Following a tissue diagnosis and staging, the treatment of patients with STS involves a multidisciplinary team approach and most patients are eligible for limb-salvage surgery, usually combined with radiation. Following treatment the majority of patients can expect a painless and functional extremity.

**Conflict of interest**

No conflicts of interest are declared by any author on this study.

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