Single-Institution, Multidisciplinary Experience with Surgical Resection of Primary Chest Wall Sarcomas

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Introduction: Primary chest wall sarcomas are rare mesenchymal tumors and their mainstay of therapy is wide surgical resection. We report our single-institution, multidisciplinary experience with full-thickness resection for primary chest wall sarcomas.

Methods: A retrospective review of our prospectively maintained databases revealed that 51 patients were referred for primary chest wall sarcomas from 1990 to 2009.

Results: All patients required resections that included rib and/or sternum. Twenty-nine patients (57%) had extended resections beyond the chest wall. Forty-two patients (82%) required prosthetic reconstruction and 17 patients (33%) had muscle flap coverage. Overall, 51% (26/51) of patients received neoadjuvant therapy. Seventy-three percent (11/15) of high-grade soft tissue sarcomas, 77% (10/13) of high-risk bony sarcomas, and 67% (4/6) of desmoid tumors were treated with induction therapy. Negative margins were obtained in 46 patients (90%). There were no perioperative mortalities. Eight patients (16%) experienced complications. Local recurrence and metastasis was detected in 14 and 23%. Five-year overall and disease-free survivals were 66% and 47%, respectively. Favorable prognostic variables for survival included age ≤50 years, tumor volume ≤200 cm^3, desmoid tumor, bony tumor, chondrosarcoma, and low-grade soft tissue sarcoma.

Conclusions: We report our multidisciplinary experience with primary chest wall sarcomas that included induction therapy in the majority of high-risk soft tissue and bony sarcomas and desmoid tumors. Despite aggressive preoperative treatments, acceptable surgical results with low morbidity and mortality can be achieved. Neoadjuvant systemic therapy may reduce local and distant recurrence and improve overall survival.

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Sarcomas are rare mesenchymal tumors that comprise less than 1% of all adult malignancies and arise from the chest wall in less than 20% of all sarcoma cases.[1–5] Many histological subtypes have been identified, which are broadly divided into soft tissue or bony types. In the United States, there are approximately 7000 cases of soft tissue and 2500 bony sarcomas reported per year.[6] Wide surgical resection with margin negativity is the mainstay of therapy. Prosthetic reconstruction and soft tissue coverage is often required after full-thickness chest wall resection to maintain chest wall stability, prevent flail chest, and preserve pulmonary function.

Although surgical resection has been the standard treatment of soft tissue and bony sarcomas, the impact of chemotherapy and/or radiation on more aggressive tumors remains unclear. It is generally well accepted that histology and grade are important factors in determining the need for multimodality treatment. Although certain bony sarcomas, such as osteosarcoma or Ewing sarcoma, have accepted and established roles for chemotherapy and radiation, the application of multimodality approaches particularly for soft tissue sarcomas is an evolving field of investigation and remains controversial.

We report our single-institution, multidisciplinary experience with (1) primary chest wall sarcomas followed by full-thickness chest wall resection and reconstruction and (2) a subset analysis of patients who received induction therapy for high-risk sarcomas. Neoadjuvant therapy (chemotherapy or chemoradiation) was used in cases of high-grade soft tissue sarcomas, high-risk bony sarcomas (i.e., osteosarcoma, Ewing, and mesenchymal or dedifferentiated chondrosarcomas), and desmoid tumors. Desmoid tumors were considered with low-grade sarcomas in this study due to their aggressive local behavior resulting in significant morbidity, and those involving the chest wall and adjacent structures are associated with a high recurrence rate despite resection with margin negativity.[7] There is a growing body of evidence to support the use of neoadjuvant therapies before surgical resection with asso-

ciated improved outcomes, particularly in situations where surgery results in morbidity with high risk for recurrence.[8,9] We evaluated patient and tumor characteristics, morbidity, mortality, and outcome data to identify prognostic factors that impact overall and disease-free survival after application of our institutional algorithm that incorporated the use of induction therapy, where applicable.

PATIENTS AND METHODS

Fifty-one patients were referred to the David Geffen School of Medicine at University of California, Los Angeles (UCLA), with primary chest wall musculoskeletal tumors from 1990 to 2009. Patients were considered for this analysis if they carried a diagnosis of a primary chest wall sarcoma and underwent a full-thickness chest wall resection and reconstruction. Chest wall neoplasm was defined as any neoplasm involving the ribs or sternum. A retrospective review of our prospectively maintained sarcoma databases was performed to identify appropriate patients. Clinical data were obtained from medical records following Institutional Review Board approval.

Histological review was performed by dedicated musculoskeletal pathologists to determine histology (soft tissue versus bony), grade, and margin status. Soft tissue sarcomas were graded using the French Federation of Cancer Centers Sarcoma Group grading system, and bony sarcomas were classified as grade 1, 2, or 3 as per convention.

A multidisciplinary musculoskeletal tumor board evaluated patients pre- and postoperatively to determine the appropriateness of neoadjuvant and adjuvant treatments. All patients were considered for multimodality therapy that included the use of induction therapy (chemotherapy, radiation, or chemoradiation) followed by full-thickness chest wall resection and reconstruction for primary sarcomas. Neoadjuvant therapy was considered in subjects with high-risk sarcomas: (1) high-grade soft tissue sarcomas, (2) high-risk bony sarcomas (osteosarcoma, Ewing sarcoma, and mesenchymal or dedifferentiated chondrosarcoma), and (3) a subset of desmoid tumors (Figure 1). All patients underwent full-thickness chest wall resection with ribs or sternum with the intent for complete resection with wide margins that included a rib above and below the tumor. Mesh reconstruction was performed with the following materials: Prolene (Ethicon, Inc., Somerville, NJ), polytetrafluoroethylene (Gore-Tex; W.L. Gore & Associates, Inc., Flagstaff, AZ), methylmethacrylate (Stryker Howmedica Osteonics, Mahway, NJ), or Marlex (Bard Davol, Cranston, RI). Soft tissue coverage, when required, was achieved with pedicled or free myocutaneous flaps. Local recurrence was defined as appearance of sarcoma in the site of previous resection. Metastasis was defined as appearance of sarcoma outside of the chest wall resection area.

The Kaplan-Meier method was used to calculate overall and disease-free survival probabilities. All survival and recurrence data were calculated from the date of surgical resection. Differences in overall and disease-free survival were determined by log-rank analysis. The following variables were evaluated for prognostic significance: age, gender, tumor volume, histology (soft tissue versus bony), grade, extent of resection, margin status, neoadjuvant therapy, and adjuvant treatments. Significance was defined as $p < 0.05$.

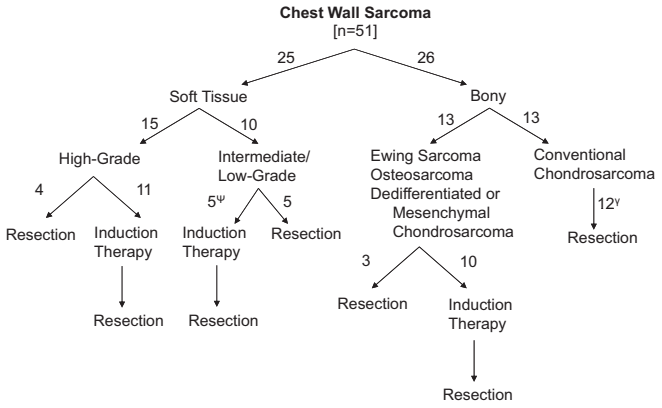

FIGURE 1. Flow chart of the treatment algorithm for chest wall sarcomas at University of California, Los Angeles (UCLA). Number of patients in each group is indicated next to the arrows. Ψ, Four patients with desmoid tumors and one patient with leiomyosarcoma received induction therapy. γ, Induction therapy data were not available for one patient with chondrosarcoma.

RESULTS

Patient and Clinical Presentation

Fifty-one patients with primary chest wall sarcomas underwent wide surgical extirpation, and of these, six patients referred from outside institutions presented with a recurrent chest wall sarcoma. Patient characteristics are described in Table 1. There were 24 males (47%) and 27 females (53%) with an average age of 50.9 years. Most patients were symptomatic with the most common symptom being pain (41%) and examination finding a palpable mass (33%). Ten patients (20%) had a history of chest wall irradiation for treatment of lymphoma or breast carcinoma with a median of 10 years (range, 4–17 years) until the development of their chest wall sarcomas.

Tumor Characteristics

The resected chest wall tumors were evaluated for size and grade (Table 1). Three patients had a complete response to neoadjuvant therapy accounting for immeasurable disease. The average tumor diameter, cross-sectional area, and volumes were 8.7 cm, 81.6 cm^2, and 611.5 cm^3, respectively. There was nearly equal distribution of tumor grade between low- or intermediate-grade (49%) and high-grade (51%) sarcomas. Histological subtypes of the resected chest wall sarcomas are described in Table 2. Bony versus soft tissue histological subtypes were evenly distributed (49% versus 51%). Bony sarcomas included chondrosarcoma, Ewing sarcoma, or osteosarcoma. There were six (12%) desmoid tumors in our study.

TABLE 1. Patient and Tumor Characteristics (Total Patients = 51)

	N	%
Age (yr)		
Average	50.9	
Range	17–90	
Sex		
Male	24	47
Female	27	53
Symptoms		
Pain	19	37
Palpable mass	17	33
Asymptomatic	3	6
Dyspnea and pain	2	4
Dyspnea	1	2
Weight loss	1	2
Unknown	8	16
History of chest wall XRT		
Yes	10	20
No	39	76
Unknown	2	4
Tumor dimensions		
Average diameter[a]	8.7 cm	
Diameter range[b]	1.5–29.5 cm	
Average volume[c]	611.5 cm^3	
Volume range[b]	1.5–6372 cm^3	
Tumor grade		
Low/intermediate	25	49
High	26	51

[a]Tumor diameter data was not available for two patients.
[b]Three patients had a complete response after neoadjuvant therapy resulting in immeasurable disease in final specimen.
[c]Tumor volume data were not available for seven patients.
XRT, radiotherapy.

TABLE 2. Histological Subtypes of Chest Wall Sarcomas

	No. of Tumors (n = 51)
Chondrosarcoma[a]	15
Ewing sarcoma/PNET	8
Radiation-associated sarcoma	6
Desmoid tumor	6
Angiosarcoma	3
Osteosarcoma	3
Dedifferentiated liposarcoma	2
Leiomyosarcoma	2
Fibrosarcoma	1
Granular cell tumor	1
Giant cell tumor	1
High-grade sarcoma NOS[b]	1
Myxofibrosarcoma	1
Synovial sarcoma	1

[a]13 conventional, 1 dedifferentiated, and 1 mesenchymal chondrosarcomas.
[b]Previously known as malignant fibrous histiocytoma.
PNET, primitive neuroectodermal tumor; NOS, not otherwise specified.

Neoadjuvant and Adjuvant Therapy

Diagnosis was obtained in 44 patients (86%) via image-guided core needle (39%; 17/44) or incisional surgical biopsy (61%; 27/44) before definitive resection of their primary chest wall sarcomas. Six patients proceeded directly to surgical resection after a chest wall tumor was identified. Twenty-six patients (51%) received neoadjuvant treatment (chemotherapy, radiation, or hormonal therapy) after the biopsies were reviewed in a multidisciplinary musculoskeletal tumor board (Figure 1 and Table 3). Patients received various chemotherapy regimens preoperatively (Table 3). Combined chemoradiation with a dose range of 45 to 60 Gy was given to patients with high-grade soft tissue sarcomas. Osteosarcomas and dedifferentiated or mesenchymal chondrosarcomas were treated with chemotherapy alone. Ewing sarcomas were treated with combined chemoradiation or chemotherapy alone. Desmoid tumors were treated with several investigational systemic therapies and/or radiation. Seventy-three percent (11/15) of high-grade soft tissue sarcomas, 77% (10/13) of high-risk bony sarcomas, and 67% (4/6) of desmoid tumors were treated with induction therapy (Figure 1). In general, patients with low-grade soft tissue sarcomas and conventional chondrosarcomas were resected without induction therapy. However, five patients with low- or intermediate-grade sarcomas received induction therapy for which four patients had desmoid tumors (Figure 1). In contrast, the majority of patients (61%; 31/51) did not receive adjuvant chemotherapy or radiotherapy.

Chest Wall Resection and Reconstruction

Surgical removal in all patients required full-thickness chest wall resection that included rib or sternum. The details of surgical resection and reconstruction are described in Table 3. An average number of 3.7 ribs were resected. Twenty-two patients (43%) had only ribs, only sternum, or both resected, whereas the remaining 29 patients (57%) had extended resections beyond just the chest wall (Table 3). A total of 12 patients (24%) required partial or complete sternectomies, including 7 patients from the extended resections group. Local extension from the chest wall sarcoma into other structures was not a contraindication to resection. The lung was most commonly involved in 14 patients (27%).

Forty-two patients (82%) required prosthetic reconstruction of chest wall defects. The types of mesh used include Prolene, polytetrafluoroethylene, or Marlex alone or in combination with methylmethacrylate (Table 3). Soft tissue coverage was required in 17 patients (33%).

Margin Status

Negative margins (R0 resection) were obtained in 46 patients (90%), whereas the remaining 5 patients (10%) had a microscopically positive margin (R1 resection; Table 3). There were no patients who underwent a grossly margin positive (R2) resection.

Complications and Hospital Course

There were no 30-day perioperative or hospital mortalities (Table 3). Eight patients (16%) experienced complications postoperatively. Surgical site infections developed in

TABLE 3. Clinical Characteristics, Surgical Resection, and Multimodality Treatments

	No. of Patients (n = 51)	%
Chest wall resection		
Average number of ribs[a]	3.7	
Range of ribs	1–10	
Ribs only	17	33
Sternum only	2	4
Sternum and ribs only	3	6
Extended resection[b]	29	57
Extended resection		
Lung	14	27
Diaphragm	6	12
Clavicle/scapula	5	10
Vertebrae	3	6
Pericardium	2	4
Adventitia of descending aorta	1	2
Brachial plexus	1	2
Other[c]	6	12
Reconstruction		
Mesh only	24	47
MMA[d] + mesh	18	35
No mesh	7	14
Unknown	2	4
Muscle flap		
Pedicled	14	27
Free	3	6
Neoadjuvant therapy		
Chemotherapy	14	27
Chemo/radiotherapy	10	20
Hormonal therapy	1	2
Hormonal/radiotherapy	1	2
None	24	47
Unknown	1	2
Adjuvant therapy		
Chemotherapy	11	21
Radiotherapy	6	12
None	31	61
Unknown	3	6
Chemotherapy regimens	24	47
Doxorubicin + ifosfamide	12	23
Ifosfamide	4	8
Gemcitabine + docetaxel	3	6
Doxorubicin	2	4
Methotrexate	2	4
Unknown	1	2
Margin status		
Negative/R0	46	90
Positive		
R1	5	10
R2	0	0
Complications		
Mortality (30 d)	0	0
None	41	80
Surgical site infection	2	4
Wound dehiscence	1	2
Pneumonia/respiratory failure	1	2
Empyema	1	2
Massive air leak/pancreatic leak	1	2
DIC/failed free muscle flap	1	2
Arrhythmia	1	2
Unknown	2	4
Hospitalization		
Median number of days	6	
Range of days	2–36	
Unknown	3	6
Outcome		
No recurrence	24	47
Local recurrence	7	14
Lung metastases	11	21
Bone metastases	1	2
Unknown	8	16

[a]The number of ribs resected data was not available for one patient.
[b]Seven patients with extended resections also required either partial or complete sternectomy.
[c]Other resections included the following: breast/pectoralis muscle/lymph nodes (1), abdominal wall (2), liver (1), sigmoid colon (1), and spleen (1).
[d]Methylmethacrylate was supplied by Stryker Howmedica Osteonics, Mahway, NJ.
MMA, methylmethacrylate; DIC, disseminated intravascular coagulation.

two patients (4%) who required surgical debridement with mesh removal, and one patient had a revision of her muscle flap. One patient (2%) had a wound dehiscence that required subsequent reoperation and mesh removal. All three patients who experienced local wound issues had prior radiation. Of these, two patients had previous history of breast cancer and received 50 Gy radiation remotely, and one patient received induction chemoradiation (unknown dose) just before surgical resection of the chest wall sarcoma.

Complications from a fungal pneumonia in one patient (2%) led to respiratory failure requiring a tracheostomy, but the patient was decannulated before hospital discharge. After developing an empyema, one patient (2%) underwent tube drainage as well as surgical debridement and mesh removal. One patient (2%) required full-thickness chest wall resection with four ribs as well as extended resection involving the diaphragm, sigmoid colon, and spleen due to a combined chest wall and retroperitoneal sarcoma. He developed both a massive air leak after inadvertent injury to the left lower lobe that required a wedge resection and a pancreatic leak that was managed nonoperatively with drainage catheters. One patient (2%) had a history of chest wall radiation and prior sarcoma resection and developed disseminated intravascular coagulation during resection of the chest wall tumor infiltrating the lung and failure of a free myocutaneous flap. She recovered well after supportive therapy in the intensive care unit but required revision with a second free myocutaneous flap. On postoperative day 4, one patient (2%) had atrial fibrillation with immediate conversion to normal sinus rhythm and was controlled with antiarrhythmic medications. The median length of hospital stay for all patients was 6 days.

Recurrence and Metastasis

Twenty-four patients (47%) had no documented recurrences at the time of last follow-up (Table 3). Eight patients (16%) did not receive follow-up care at UCLA

TABLE 4. Survival and Disease-Free Interval Data after Chest Wall Resection

	N	5-yr Survival (%)	Log-rank *p*	5-yr Disease-Free Survival (%)	Log-rank *p*
Age					
≤50 yr	26	76	0.004	64	NS
>50 yr	25	50		32	
Gender					
Male	24	65	NS	38	NS
Female	27	61		60	
Tumor volume					
≤200 cm^3	23	75	0.04	31	NS
>200 cm^3	21	51		72	
Histology					
Bony	26	67	0.02	42	NS
Soft tissue	19	46		34	
Desmoid	6	100		100	
Bony					
Chondrosarcoma	15	85	0.02	42	0.03
Ewing/PNET	8	63		60	
Osteosarcoma	3	0		0	
Soft tissue					
Low-grade	4	67	0.04	100	0.03
High-grade	15	43		22	
Desmoid	6	100		100	
Extended resection					
Yes	36	55	NS	41	NS
No	15	79		61	
Sternal resection					
Yes	12	75	NS	65	NS
No	39	58		41	
Margin status (excluding desmoids)					
Positive (R1)	4	25	NS	50	NS
Negative (R0)	41	63		39	
Neoadjuvant therapy					
Yes	26	49	NS	34	NS
No	24	76		60	
Adjuvant therapy					
Yes	17	54	NS	25	NS
No	31	66		61	

NS, not significant; PNET, primitive neuroectodermal tumor.

after initial perioperative care. Local recurrence and metastasis was detected in 14% and 23%, respectively. A total of 16 patients (31%) received preoperative or postoperative radiation therapy, and of these, 2 patients developed a local recurrence. One patient received both neoadjuvant and adjuvant radiation.

Of the seven patients (14%) with a local recurrence, four had low-grade and three had high-grade sarcomas. None of the seven patients received adjuvant radiation. However, two of these patients received induction radiation. Only one of the seven patients had a microscopically positive (R1) resection margin.

The most common site of metastasis was the lung (21%). One patient (2%) who presented with a local recurrence after initial chest wall resection had a synchronous lung metastasis. All other patients had no evidence of metastasis at the time of chest wall resection.

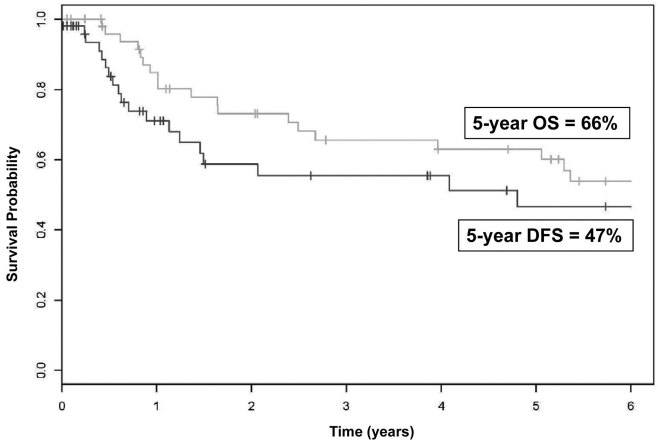

FIGURE 2. Outcome of all patients with bony and soft tissue sarcomas. The 5-year overall survival (OS) of all patients is 66%. The 5-year disease-free survival (DFS) is 47%.

Overall Survival and Disease-Free Survival

The 5-year overall survival and disease-free survival after surgical resection of primary chest wall sarcomas for variables that included age, gender, tumor volume, histology (bony and soft tissue origins), extended or sternal resection, margin status, and neoadjuvant and adjuvant therapy are described in Table 4. The 5-year overall survival and disease-free survival for all patients (soft tissue and bony sarcomas) were 66% and 47%, respectively (Figure 2). Table 4 describes favorable prognostic variables for 5-year overall survival which included age ≤50 years, tumor volume ≤200 cm^3, desmoid tumor, bony tumor, chondrosarcoma, and low-grade soft tissue sarcoma. Favorable prognostic factors for disease-free survival included chondrosarcoma and low-grade soft tissue sarcoma. The need for extended or sternal resections did not portend a worse survival or recurrence outcome. Negative margin status in chest wall sarcomas, excluding desmoids, showed improved survival (63% versus 25% 5-year survival) but did not achieve statistical significance presumably due to the limited number of resections with positive microscopic margins (four patients; Table 4). The survival outcomes did not change significantly with inclusion of desmoid tumors (data not shown).

DISCUSSION

Although wide surgical resection is the established standard treatment for all sarcomas, approximately 50% of patients with high-risk soft tissue sarcomas will develop metastatic disease despite optimal local treatment with the majority occurring within 2 years of surgical resection and ultimately succumbing to their disease.[10] Presumably, many of these patients have micrometastatic disease at presentation. Once macroscopic metastatic disease is evident, the median survival is 11.7 months.[11] Although certain bony sarcomas, such as osteosarcoma or Ewing sarcoma, have accepted and

established roles for chemotherapy and radiation, the application of multimodality treatments for soft tissue sarcomas remains controversial. Doxorubicin, dacarbazine, and ifosfamide have consistently been associated with response rates of about 20% or more in high-grade soft tissue sarcomas.[12] Response rates to high-dose ifosfamide or in combination with doxorubicin have shown more favorable response rates of 20 to 60% in some series.[12–17] However, despite extensive research, there is still no clear answer as to whether adjuvant or neoadjuvant chemotherapy can improve survival in patients with soft tissue sarcomas.

There have been many reports in the literature describing the experience with surgical resection of primary or recurrent chest wall sarcomas.[2–5,18–21] The majority of these studies, however, did not involve or describe the impact of neoadjuvant therapy on surgical resection. Herein, we report our multidisciplinary approach to primary chest wall sarcomas involving full-thickness chest wall resection and reconstruction and describe our results of resection after induction therapy for high-risk sarcomas. Neoadjuvant therapy (chemotherapy or chemoradiation) was given for high-grade soft tissue sarcomas, high-risk bony sarcomas (i.e., osteosarcoma, Ewing, and mesenchymal or dedifferentiated chondrosarcomas), and desmoid tumors. Desmoid tumors were grouped with low-grade sarcomas due to their aggressive local behavior and associated significant morbidity, and thus investigational agents were considered before surgical resection.

Although neither this study nor others have directly addressed whether neoadjuvant or adjuvant therapy is more efficacious for primary chest wall sarcomas, there are some clear advantages to induction therapy, which include (1) tumor volume reduction and increased tumor necrosis with improved likelihood of complete resection, (2) immediate systemic therapy for micrometastatic disease, and (3) pathologic evaluation of effectiveness of preoperative therapy after surgical resection. It is on this basis that our institutional preference is preoperative therapy whenever applicable.

In our series, 73% of high-grade soft tissue sarcomas, 77% of high-risk bony sarcomas, and 67% of desmoid tumors were treated with induction therapy. Overall, 51% of patients received neoadjuvant treatment (chemotherapy, radiation, or hormonal therapy) before surgical resection. Our algorithmic approach resulted in a substantially higher percentage of patients receiving induction therapy compared with other series where 0 to 27% of patients received preoperative systemic treatment, with the exception of the Walsh et al. study in which similarly 51% of patients with soft tissue or bony sarcomas received preoperative therapy.[4,5,18–21] Despite the relatively high percentage of patients undergoing induction therapy, complete resection was achieved in the majority of our patients with a 16% complication rate and no 30-day postoperative mortality. Our morbidity and mortality rates are comparable to other reports of 13 to 24% and 0 to 1.7%, respectively, in which only a minority of patients underwent initial induction treatment.[2–5,18–21] As such, preoperative therapy does not seem to increase morbidity or mortality associated with chest wall resections at our institution.

Combined chemoradiation was given in patients with high-grade soft tissue sarcomas and certain bony sarcomas (i.e., Ewing sarcoma) preoperatively. Despite the utilization of radiation in these instances, we experienced acceptable wound complication rates (4% infection and 2% dehiscence). Interestingly, all three patients who experienced local wound issues had prior radiation. Two patients had received 50 Gy radiation remotely for breast cancer, and one patient received induction chemoradiation (unknown dose) just before surgical resection. In a prospective randomized trial, O'Sullivan et al. [22] reported more frequent wound complications in patients with soft tissue sarcomas of the extremity that received preoperative (35%) compared with postoperative (17%) radiation with a preoperative radiation dose of 50 Gy. In this study, when radiation was used preoperatively with chemotherapy, the dose range was 45 to 60 Gy. However, in our more recent experience, we have limited the radiation dose to

TABLE 5. Publications of Primary Chest Wall Sarcoma Experience (2000–2011)

Author (yr)	Patients	Sarcoma Type	High-Grade Sarcomas	Morbidity	30-d Mortality	Recurrence		5-yr OS	5-yr DFS	Neoadjuvant Therapy			Adjuvant Therapy		
						Local	Distant			C-XRT	C	XRT	C-XRT	C	XRT
Our Study (2011)	51	STS/bone	51%	16%	0%	14%	23%	66%	47%	22%	29%	0%	0%	21%	12%
van Geel et al. (2010)	60	STS/bone	63%	22%	1.7%	33%	48%	46%	30%	0%	0%	0%	0%	0%	27%
Tsukushi et al. (2009)	44	STS	50%	Unk	Unk	11%	7%	89%	89%	Unk	Unk	Unk	0%	9%	9%
Wouters et al. (2008)	83	STS/bone	38%	20%	0%	41%[a]	58%[a]	63%	Unk	0%	20%	2%	0%	17%	30%
Pfannschmidt et al. (2006)	25	STS	52%	0%	0%	36%	56%	57%	Unk	0%	4%	4%	0%	12%	8%
Gross et al. (2005)	55	STS	42%	Unk	Unk	11%	18%	87%	75%	27%	0%	0%	0%	0%	4%
Walsh et al. (2001)	51	STS/bone	53%	24%	0%	18%	24%	64%	54%	2%	43%	6%	8%	18%	0%

OS, overall survival; DFS, disease-free survival; C-XRT, chemoradiation; C, chemotherapy; XRT, radiation therapy; STS, soft tissue sarcoma; Unk, unknown.
[a]Refers to the entire primary chest wall sarcoma group with no specification to neoadjuvant or adjuvant therapy.

45 Gy in the preoperative setting to prevent local wound issues, and muscle flap reconstruction of the chest wall is universally performed in the setting of preoperative radiation or remote history of radiation in the field of chest wall resection. The application of muscle flaps is likely to have reduced local wound complications and contributed to the overall acceptable morbidity and no mortality in our study.

In reviewing the literature of studies published since 2000 that adequately described multimodality treatments, the incorporation of neoadjuvant systemic therapy before surgical resection of primary chest wall sarcomas seems to have more favorable long-term outcome with respect to local and distant recurrence (Table 5). In this study, 51% of patients with soft tissue or bony sarcomas received induction systemic therapy with a local recurrence of 14% and distant recurrence of 23%. These findings are similar to the studies from Walsh et al. and Gross et al.[4,19] In contrast, studies that did not incorporate systemic therapy in a multimodality fashion with surgery had poorer outcomes with respect to recurrence.[5,18,21] The use of adjuvant radiation did not seem to have a clear relationship with local recurrence.[4,5,18–21] In most series, postoperative radiation was given in up to 9% of patients (Table 5). However, van Geel et al. and Wouters et al. described the utilization of adjuvant radiation in 27% and 30% of patients, but they still reported relatively high overall local recurrence rates of 33% and 41%, respectively.[5,18] The overall survival seems to be more favorable in series that incorporated the use of systemic therapy. Our survival results were comparable with the survival ranges in the published literature where neoadjuvant systemic therapy was used (63–87%).[4,5,19,21] Thus, the use of systemic therapy in high-risk sarcomas may contribute to improved overall survival. However, it remains unclear whether neoadjuvant or adjuvant chemotherapy is more effective.

In summary, we report our multidisciplinary approach and experience with treatment of primary chest wall sarcomas and the application of induction therapies in high-risk soft tissue and bony sarcomas. A multidisciplinary discussion before treatment initiation is required for optimal therapy. Despite aggressive preoperative treatments, acceptable surgical results and long-term outcomes can be achieved with complex, full-thickness chest wall resections and reconstructions. Multispecialty teams may be required for more complex operations. Extended resections beyond the chest wall was not associated with worse outcome. The use of neoadjuvant systemic therapy in primary chest wall sarcomas seems to portend a more favorable long-term outcome but warrants further exploration and validation.

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