Review of Chest Wall Tumors: A Diagnostic, Therapeutic, and Reconstructive Challenge

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ABSTRACT

Chest wall tumors are a heterogeneous group of lesions that provide an interesting diagnostic and therapeutic challenge for surgeons. They make up less than 5% of thoracic malignancies and vary widely in pathology as they arise from all anatomic structures of the chest wall. In general, treatment is wide local excision, the margins for malignant disease are necessarily wider, and adjuvant radiation is typically given for those with positive margins. Chemotherapy is rarely effective. Local control is the most important prognostic factor. Disease-free survival for malignant disease is limited by positive margins; therefore full oncologic resection with 4-cm margins should be attempted. For small lesions, the resection and reconstruction is usually straightforward. For more advanced disease or those lesions that require significant functional loss, preoperative planning using a multidisciplinary approach, incorporating thoracic surgery, plastic surgery, neurosurgery, radiation medicine, oncology, and physical medicine and rehabilitation, may be essential.

KEYWORDS: Chest wall tumor, primary chest wall tumor, chest wall resection

The musculoskeletal structure of the chest wall serves a critical role in the protection of thoracic and mediastinal viscera and provides integrity for respiratory function. Intricate knowledge of the anatomy and physiology is required of all surgeons who operate in this area for resection or reconstruction. The complex relationships of blood vessels, nerves, bone, cartilage, and muscle allow the chest wall to serve its anatomic function but also make it susceptible to pathology that varies widely.

Tumors of the chest wall can vary from benign to malignant and arise from any soft tissue or bony structure. More than 50% of chest wall tumors are malignant, typically involving direct invasion or metastases from adjacent thoracic tumors.¹ The challenges of diagnosis, complete resection, and reconstruction have posed difficulty for surgeons attempting to minimize perioperative

morbidity in the past, but advances in all of these areas have greatly improved long-term survival and decreased recurrence rates.²

This article serves to review the pathology, options for diagnosis, and standard treatment of the various lesions arising from the chest wall.

EVALUATION OF A CHEST WALL MASS

Symptoms and Signs

Chest wall tumors can vary from symptomatic to asymptomatic, with more than 20% being found incidentally on chest radiograph.³ Extrathoracic lesions are more likely to present as a growing mass (Fig. 1). Pain is the most common symptom for both benign and malignant

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Figure 1 Anterior chest wall mass in an 80-year-old farmer.

tumors. With malignant tumors, this is usually from bony involvement and is frequently a sign of invasion. There is wide variation in age at presentation with older patients tending to have larger and more aggressive tumors compared with their younger counterparts, who are more likely to have smaller, benign tumors.³

Diagnosis

Because of the wide variation in histology of origin in chest wall tumors, radiographic diagnosis can be challenging. It is frequently necessary to use imaging appearance, location, and clinical information to make a diagnosis rather than imaging alone.⁴ Chest radiography, computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) can all be used to assess a chest wall tumor. Chest radiography can detect calcification, ossification, or bone destruction as well as location and size but is limited in detail. CT can provide information about the vascularity of a tumor, if contrast is used, as well as a more detailed appraisal of extent, location, and composition of the mass (Fig. 2A). MRI is an important tool of assessment because of its superior tissue-resolving features and multiplanar image acquisition, which allows accurate tissue characterization (Fig. 2B).^{4,5} Because of the rarity of these lesions and the recent availability of PET, it has not been formally established as a diagnostic tool in the evaluation of these lesions.² The clinical significance of standard uptake value (SUV) may become useful in the future as more data become available. In the case of malignant disease and other radiographic abnormalities,

Figure 2 (A) CT image of a posterior chest wall sarcoma presenting as a painless growing mass in a 61-year-old man. (B) MRI scan of chest wall mass demonstrating heterogeneity. (C) PET CT image of an isolated metastatic left anterior chest wall lesion from breast cancer.

PET may be useful for defining those patients with limited disease versus disseminated disease (Fig. 2C).

Biopsy

In the majority of cases, radiographic features alone are insufficient to make a complete diagnosis, and therefore histologic evaluation is required. Fine-needle aspiration, incisional biopsy, or excisional biopsy are all suitable modalities to obtain a tissue diagnosis.² The decision of one approach over the other is usually based on the size of the lesion, extent of resection, need for reconstruction, and associated comorbidities. Typically, lesions less than 5 cm undergo excisional biopsy, and lesions greater than 5 cm may either undergo needle aspiration or incisional biopsy. This strategy is based primarily on the extent of resection and complexity of reconstruction that would need to take place, thereby making the absolute diagnosis of value prior to resection. Given this, it is essential that the entire treatment plan be considered before any biopsy occurs to ensure correct placement of skin incisions if re-excision is required.

Preoperative Evaluation

Once the diagnosis has been made or primary excision is planned, it is important to complete a medical evaluation with careful consideration of past surgical history that may affect approaches for resection or reconstruction. A careful surgical history is of critical value as we progress in our management of isolated metastatic disease. As an example, use of a latissimus dorsi flap may not be possible to reconstruct an isolated chest wall defect if the patient had an ipsilateral lumpectomy with adjuvant radiation therapy or nodal dissection.

Thus, immunosuppression, history of radiation or planned radiation, and previous chest procedures should all be considered when planning the operative approach. Additionally, full medical clearance should be obtained including a cardiac and pulmonary function evaluation in cases where there is concern over postoperative pulmonary function. As mentioned earlier, complete radiographic analysis is essential to operative planning and may delineate the need for preoperative consultation with neurosurgical or reconstructive specialists. Patients with extensive or complicated lesions are best served with a multidisciplinary approach.⁶

Surgical Management

Chest wall resection is the primary treatment modality for chest wall tumors and can be performed with low morbidity and mortality. If tumors are chemo-sensitive, preoperative chemotherapy should be administered to reduce the amount of tumor burden. Osteosarcoma, rhabdomyosarcoma, Ewing sarcoma, and other small-

cell sarcomas should be treated with chemotherapy in a neoadjuvant setting, then continued postoperatively depending on tumor response. Chondrosarcomas and other adult soft tissue sarcomas are typically excised surgically and irradiated if negative margins cannot be achieved. Resection can prolong survival and provide palliation for symptomatic lesions.⁷

Use of epidural catheters for postoperative pain control can minimize postoperative morbidity and mortality in these patients. As well, depending on the extent of pulmonary involvement, a double lumen endotracheal tube may be required to allow for concurrent pulmonary resection. Appropriate margins are dependent on the histology of the tumor and are a key predictor of recurrence-free survival.⁸ For chondrosarcomas, local recurrence rate is 4% with negative margins and 73% with positive margins.⁹ For aggressive malignancies that can spread along the periosteum, the entire rib should be resected with costal articulations either posteriorly or anteriorly depending on tumor location. Sections of ribs above and below the tumor should be resected as well. For high-grade malignancies, 4-cm margins are adequate, and low-grade malignancies can be treated with 1- to 2-cm margins. Desmoid tumors are not technically malignant, but their behavior is so aggressive that one should use 4-cm margins for these lesions when possible. Any involved soft tissue, skin, underlying pleura, or lung tissue should be resected with the tumor, provided pulmonary function permits resection. Placing a thoracoscope in the chest, away from the lesion, may be useful to determine extent of pulmonary involvement and exact location when the lesion is not palpable. When necessary, a needle can be inserted into the chest under thoroscopic guidance to aid in operative planning.

Adequate oncologic resection should not be compromised for concern over chest wall defect; however, the integrity of the chest wall should be maintained to avoid pulmonary compromise. Chest wall reconstruction will be addressed in more detail elsewhere, but the following tenants should be followed.

1. Defects less than 4 to 5 cm typically do not require reconstruction.
2. Posterior defects covered by the scapula do not require reconstruction.
3. Skeletal stabilization is achieved with autologous tissue, mesh, Gore-Tex, (W.L. Gore and Associates, Inc., Flagstaff, AZ) or methyl methacrylate "sandwich" reconstruction (Fig. 3).
4. Soft tissue reconstruction can be performed using myocutaneous or omental flaps.

Postoperative pulmonary toilet is vitally important because large anterior defects can result in weak cough and inability to clear secretions. Bronchoscopy

Figure 3 Methyl methacrylate and mesh reconstruction of the right anterior chest wall seen on a follow-up CT.

may be necessary to facilitate adequate pulmonary toilet.

Pathology

In the next few sections, we will briefly describe individual tumors of the chest wall and their management.

BENIGN LESIONS

Skeletal Lesions Benign chest wall tumors are less common than malignant lesions and arise from nerve, blood vessel, osseous, cartilaginous, or fatty tissue origin.⁴ It is crucial that malignant diagnoses are definitively ruled out with radiographic and histologic analysis for any of these lesions.

Osteochondroma is the most common type of benign bone tumor and is typically found in the femur, humerus, and tibia.¹⁰ However, in the chest, osteochondromas are most common in the rib or scapula, where they are commonly found at the costochondral junction, and they develop from abnormal growth of normal tissue.⁴ Osteochondromas make up 50% of benign rib tumors.² These masses frequently cause pain as they progress with growth of bony exostoses.¹⁰ Surgical treatment is resection and provides complete pathologic evaluation, symptomatic relief, and minimizes the risk of malignant transformation.¹¹

Chondromas are typically found at the sternocostal junction arising from cartilaginous tissue.² They are relatively common, making up 15 to 20% of benign chest wall lesions. Chondromas are usually painless, slow growing, and present between 20 and 30 years of age. The distinction between chondroma and low-grade chondrosarcoma is difficult, therefore all chondromas are treated as malignant lesions, and wide excision is recommended.³

Fibrous dysplasia typically appears in the lateral or posterior tract of the ribs and is the third most frequent

benign chest wall lesion.² Normal bone is replaced with fibrous tissue forming a slow-growing mass, which can cause pathologic fractures and result in pain; otherwise, presentation may be as an asymptomatic mass in the posterior aspect of a rib. Fibrous dysplasia appears as a lytic lesion on chest radiograph with a soap bubble or ground-glass appearance that is diagnostic. Treatment is wide local excision for relief of symptoms and confirmation of diagnosis.³

Eosinophilic granuloma, or Langerhans cell histiocytosis, is a less common tumor that can arise in the anterior chest wall.³ These masses tend to present with chest pain, fevers, and an isolated tender mass that has a typical lytic appearance on radiograph and chest CT.¹² Eosinophilic granuloma is a diffuse infiltrative inflammatory process that can affect many organs. In the chest wall, it can cause destruction of bone cortex and new subperiosteal bone formation that can mimic osteomyelitis or malignancy.³ Treatment is wide local excision both for diagnosis and symptomatic relief.^{12,13}

Soft Tissue Lesions The soft tissue tumors that affect the chest wall have a similar variability in pathology as that of the bone-based lesions. Cutaneous nevi, lipomas, hemangiomas, lymphangiomas, and neurogenic tumors are some of the benign lesions that can be found in the soft tissue of the chest wall. They are treated with wide local excision to negative margins to avoid local tissue recurrence. Intercostal hernias have also been reported that can be confused with benign soft tissue lesions, mandating appropriate radiographic confirmation of clinical suspicion based on history and physical exam.¹⁴ Radiographic evaluation may not always definitively address malignancy but will assist in operative planning. Takamori et al report a case of a large tumor (6 × 4 cm) with preoperative MRI suggestive of intrathoracic involvement; however, at exploration a benign lipoma with intramuscular growth into the intercostals was found.¹⁵ Additionally, Ozpolat et al report a case of a giant lipoma (35 × 20 × 15 cm) that was also believed to be invading the chest wall on preoperative MRI, but operative exploration revealed a subcutaneous lesion with benign pathology.¹⁶ Chest wall lipomas should be excised for symptomatic relief and complete diagnostic evaluation.

Lymphangiomas of the chest wall usually can be cystic or cavernous in nature and are a result of a developmental malformation. They can be located within the mediastinum or the chest wall itself. Preoperative CT imaging is essential to assess the extent of the lesion, as several reports of giant lesions exist in the literature.^{17,18} Complete surgical excision is required for excellent prognosis and avoidance of long-term lymphatic fistula formation. Nonoperative therapy with radiation or sclerosing agents remains controversial for lymphangiomas of the chest wall, with surgery as the standard of care.¹⁸

Hemangiomas can be found within the chest wall or protruding through the chest wall from the thoracic cavities or mediastinum and arise from blood vessels. MRI is used to distinguish benign from malignant lesions based on phleboliths, fat component, and high-intensity and fat-suppression on T2 imaging technique, but surgical biopsy is required for definitive diagnosis.¹⁹ Hemangiomas of the chest wall can be intramuscular, intercostal, or cavernous. They tend to occur in younger patients (<30 years of age) and present as painful masses. Treatment is complete surgical excision if symptomatic, but local recurrence rates are as high as 20%.²⁰

Neurogenic tumors of the chest wall include neurofibromas and neurilemmomas that arise from peripheral nerve sheaths and are usually associated with neurofibromatosis. Surgical excision is usually only recommended for cosmetic reasons for cutaneous lesions as there is a low likelihood of malignancy. However, plexiform lesions are associated with nerve roots and have a high potential to transform into malignant lesions. Plexiform lesions that are increasing in size or becoming symptomatic should be completely excised without preoperative biopsy.²¹

Desmoid tumors arise from musculo-aponeurotic structures and are considered myofibroblastic or fibroblastic in origin. They can develop anywhere in the body

but are most common in the extremities, with only 10 to 28% arising in the chest wall.¹ Their histology is benign, but because of their aggressive growth rates and tendency to grow into nearby structures or cause compressive symptoms, they can be considered malignant. Desmoid tumors are common in females and males usually younger than 40 years and can be found in patients with familial adenomatous polyposis, where they are related to a mutation in the APC gene. Desmoids can also occur in sites of previous trauma, scar, or radiation (Fig. 4A). Resection to tumor-free margins is needed for cure (Fig. 4B–D). When negative margins are not possible, radiation should be considered.²² Recurrence rates for desmoid tumors are high. Abbas et al report 5-year probability of developing a local recurrence as 37%, with an 89% rate in patients who had positive margins at the time of resection.²³

MALIGNANT LESIONS: PRIMARY TUMORS

Skeletal Lesions Bony malignant chest wall tumors account for 55% of all chest wall masses and have an average 5-year survival of 60%.³ Malignant lesions tend to grow faster, manifest more painfully, and present as larger masses than benign lesions.²⁴

Figure 4 (A) CT image of a desmoid tumor arising in a young woman below an augmentation mammoplasty implant. (B) Intraoperative photograph of the resection of the anterior chest wall ribs with the underlying lung. (C) Intraoperative photograph of the methyl methacrylate and mesh reconstruction. (D) Postreconstruction, the approach through an inframammary incision with an additional lateral wound excision of the biopsy site.

Chondrosarcomas are most commonly found on the anterior chest wall and account for 30% of primary malignant bone tumors.²⁵ They are the most common malignant bony tumor of the chest wall. Chondrosarcomas are rarely found in patients younger than 20 years of age and are found more commonly in the third and fourth decades.³ These tumors represent a malignant degeneration of the benign chondroma, with both tumors having similar clinical presentations of painful, hard, slow growing, fixed masses on the anterior chest wall.²⁶ Additionally, they can be associated with trauma.³ Radiographic appearance is typically a poorly defined mass associated with cortical destruction, and CT usually delineates a lobulated mass of soft tissue attenuation with dense chondroid matrix calcification.²⁴ Synchronous or metachronous lung metastases are seen in 10% of patients at the time of presentation.³ Pathologic distinction between chondroma and chondrosarcoma is challenging, therefore both tumors are resected with 4-cm margins. Resection is the mainstay of therapy, chemotherapy is largely ineffective, and radiation is reserved for patients who are unresectable or with positive resection margins.²⁶ Five-year survival is 65 to 92%. Tumor-free margin is the largest predictor of local recurrence. Ten percent of patients with negative margins will have local recurrence; whereas 75% of those with positive margins will have local recurrence.³

Osteosarcomas make up 10 to 15% of malignant chest wall tumors, commonly occurring in the rib, scapula, and clavicles.^{3,24} These tumors present as painful masses in young or elderly adults. Metastatic disease at the time of presentation is common, with the most common sites being lung, lymph nodes, and liver. The mass appears calcified on imaging with lytic or sclerotic osteoid bone matrix in the mass.²⁴ Treatment is wide local excision in combination with chemotherapy. The presence of metastases drastically affects 5-year survival, decreasing it from more than 50% to between 15 and 20%. Response to chemotherapy, tumor burden, and presence of metastases are predictive of overall survival.³

The Ewing sarcoma group of tumors is a spectrum of small round-cell tumors including Ewing sarcoma, Askin tumor of the chest wall, and primitive neuroectodermal tumor. These tumors are the third most common malignant chest wall tumors overall but are the most common in the pediatric and young adult populations. The Ewing sarcoma family is an aggressive tumor family with high recurrence rates and high likelihood of metastases.²⁷ Neoadjuvant chemotherapy is typically given followed by wide local excision with good results. Response to chemotherapy is predictive of local recurrence. Metastases reduce 5-year survival to 30% from 100% with local disease at presentation.³

Solitary plasmacytoma is a rare tumor composed of monoclonal plasma cells, as in multiple myeloma; however, this is a discrete mass without diffuse spread.

This tumor affects elderly men who present with pain without a mass. Once surgical biopsy has been performed, surgical therapy stops because this tumor is treated primarily with radiation.²⁸ Five-year survival is 40 to 60%, and overall survival is dependent on whether or not multiple myeloma develops and not on control of the primary lesion.³

Soft Tissue Lesions Soft tissue sarcomas are the majority of primary malignant chest wall lesions, but they account for only 6% of soft tissue sarcomas in the body. They are typically found in middle-aged men who present with a painless mass, except rhabdomyosarcomas, which are more common in children.¹ We will review some of the histologic subtypes below.

Malignant fibrous histiocytomas (MFHs) are found in the chest wall but are very common throughout the body, most commonly in the extremities, abdomen, or retroperitoneum. MFH is commonly found in elderly men, and there is usually a history of previous chest wall radiation.²⁹ The masses can grow to be a large size but are usually not painful.²¹ MFH has a heterogeneous appearance on CT that can be enhancing or calcified. Treatment is wide local excision, and local recurrence rates are higher than 30%.²⁹ Metastatic lesions are diagnosed in 30 to 50% of patients, and 5-year survival is only 38%.²¹

Liposarcomas are one of the most common malignant soft tissue tumors in the body, but they are not common in the chest wall.³⁰ They are rarely found in children and are most common in men ages 40 to 60 years. It is not unusual for them to be large and frequently associated with trauma. Treatment is wide local excision, and 5-year survival is 60%.²¹ Local recurrence rates are high, and there is little to no role for chemotherapy and radiation.

Neurofibrosarcomas are typically associated with neurofibromatosis and grow along intercostal nerves. They usually affect men in the third and fourth decades of life, who present with painful masses. Treatment is with wide local excision and postoperative radiation regardless of surgical margins. Currently, 5-year survival is 55%.²¹ Angiosarcoma of the chest wall is a rare vascular tumor that occurs in adults and is associated with chronic lymphedema, irradiation, and chemical exposure.²⁴ The most common clinical presentation of angiosarcoma of the chest wall is after radiation therapy for breast conservation therapy after breast cancer. Patients commonly present 5 to 10 years after radiation therapy, and 5-year survival after diagnosis is only 16%.³¹ Wide local excision is the only option for therapy, as most patients cannot have more radiation, and chemotherapy is usually ineffective.

Radiation-associated malignant tumors of the chest wall are uncommon, but not rare.¹ Cancers of the breast and lung or lymphomas are common indications

Figure 5 (A) Sternectomy specimen from an excision of chest wall metastasectomy, after radiation therapy. (B) Intraoperative photograph of the bed of resection demonstrating the lung and underlying pericardium. (C) Reconstruction created from mesh and methyl methacrylate. (D) Reconstruction being secured in place.

for radiation to the chest. In a large series from Memorial Sloan-Kettering Cancer Center, in 361 patients, 21 (6%) chest wall tumors arose in patients with a history of radiation to the chest. These patients were all treated with resection and had similar survival as that of patients with tumors arising *de novo*.³²

MALIGNANT LESIONS: METASTATIC DISEASE

Not all chest wall tumors are primary. Metastatic lesions from breast, lung, or unknown primary tumors can be found in the chest wall, and the role for surgical resection is gaining clarity. In the case of unknown primaries, chest wall lesions are treated like a primary tumor with resection for tissue diagnosis and therapy.³³ For breast cancers, formal studies are still lacking, but one large series from Chicago found an increase in survival with control of a chest wall lesion with either surgery or radiation.³⁴ Chest wall and sternal resection for metastatic cancers is associated with relief of pain and ulceration and bleeding caused by disease recurrence (Fig. 5 and Fig. 6).

Because of the increased knowledge and subsequent treatment options for patients with many types of

advanced cancer, the survivability of those with stage IV disease appears to have been increased. This is pertinent to those with breast cancer, colon cancer, or prostate cancer among others. In these patients, hormonal therapy or other biologic agents have allowed us to control

Figure 6 Follow-up CT image of anterior sternal reconstruction.

what was once a lethal disease, at least for a period of time. In this setting, for those patients with limited identifiable disease, as in a solitary skeletal metastasis, resection and reconstruction becomes a valid option. This is especially pertinent as the morbidity and mortality associated with these reconstructions have decreased dramatically over the past several years. At our institution, cases of small rib lesions with uncomplicated mesh reconstructions are sent home on the same day or the first postoperative day.

Given the nature of previous treatment for different primary cancers, one must be acutely aware of potential impact of previous operations or treatments on potential reconstructive options. For example, in the case of breast cancer, the thoracodorsal vessels may not be the best option for a muscular reconstruction for an ipsilateral chest wall resection. As well, if the inferior epigastrics were ligated for a previous colectomy, and one needs to resect the mammary vessels as part of the chest wall resection, the rectus will also not be a viable reconstructive option. The greater omentum may be a great alternative in this setting; however, this is insufficient in very thin patients.

PEDIATRIC TUMORS

Like tumors in their adult counterparts, pediatric chest wall tumors are varied in their histology, presentation, and age of onset; however, they have their own diagnostic and therapeutic challenges.³⁵ Approximately 20% of chest tumors in childhood are located in the chest wall, and histologic diagnoses can range from benign to malignant and infectious to noninfectious.³⁶ There is also wide variability in incidence of disease by country, for example in North America malignancies are more common diagnoses, but in underdeveloped countries tuberculosis of the chest wall is more prevalent. Ewing sarcoma is the most common malignant diagnosis in children, in comparison with adults where chondrosarcomas are the most common.³⁷

Because of the young age of pediatric patients, both survival data and long-term effects of treatment have to be considered in multidisciplinary treatment planning. Chemotherapy and aggressive surgical resection are the mainstays of therapy with a goal to avoid radiation therapy where possible. Preoperative chemotherapy is given to most chemosensitive tumors to allow for improved local control, less extensive surgery, and to treat micrometastatic disease. Scoliosis, restrictive pulmonary function, hypoplasia of soft tissues, and secondary tumors are some of the long-term sequelae that can be seen in children after treatment of a chest wall tumor.³⁷

CONCLUSION

Chest wall tumors are an interesting diagnostic and therapeutic challenge for thoracic surgeons and recon-

structive surgeons. Careful preoperative evaluation of the patient, radiographic imaging, and histopathology is required. Chest wall tumors should be resected with wide margins. Neoadjuvant or adjuvant therapy should be used to facilitate negative margins in appropriate cases. For many patients, a multidisciplinary approach is necessary for optimal outcome as it relates to cancer mortality and long-term function. Excellent outcomes for patients with benign, primary malignant, and metastatic lesions of the chest wall can be obtained with complete surgical resection and appropriate reconstruction.

REFERENCES

1. Park BJ, Flores RM. Chest wall tumors. In: Shields TW, Locicero J, Reed CE, Feins RH eds. *General Thoracic Surgery*. Philadelphia, PA: Lippincott; 2009:669–678
2. Incarbone M, Pastorino U. Surgical treatment of chest wall tumors. *World J Surg* 2001;25:218–230
3. Shah AA, D'Amico TA. Primary chest wall tumors. *J Am Coll Surg* 2010;210:360–366
4. Tateishi U, Gladish GW, Kusumoto M, et al. Chest wall tumors: radiologic findings and pathologic correlation: part 1. Benign tumors. *Radiographics* 2003;23:1477–1490
5. Lee TJ, Collins J. MR imaging evaluation of disorders of the chest wall. *Magn Reson Imaging Clin N Am* 2008;16:355–379, x
6. Kucharczuk JC, Kaiser LR. Chest wall resections. In: Kaiser LR, Kron IL, Spray TL, eds. *Mastery of Cardiothoracic Surgery*. Philadelphia, PA: Lippincott; 2007:222–227
7. Ryan MB, McMurtrey MJ, Roth JA. Current management of chest-wall tumors. *Surg Clin North Am* 1989;69:1061–1080
8. King RM, Pairolero PC, Trastek VF, Piehler JM, Payne WS, Bernatz PE. Primary chest wall tumors: factors affecting survival. *Ann Thorac Surg* 1986;41:597–601
9. Widhe B, Bauer HCF; Scandinavian Sarcoma Group. Surgical treatment is decisive for outcome in chondrosarcoma of the chest wall: a population-based Scandinavian Sarcoma Group study of 106 patients. *J Thorac Cardiovasc Surg* 2009;137:610–614
10. Tomo H, Ito Y, Aono M, Takaoka K. Chest wall deformity associated with osteochondroma of the scapula: a case report and review of the literature. *J Shoulder Elbow Surg* 2005;14:103–106
11. Shackcloth MJ, Page RD. Scapular osteochondroma with reactive bursitis presenting as a chest wall tumour. *Eur J Cardiothorac Surg* 2000;18:495–496
12. Eroglu A, Krkuglu IC, Karaoglanoglu N. Solitary eosinophilic granuloma of sternum. *Ann Thorac Surg* 2004;77:329–331
13. Bayram AS, Kprglu M, Filiz G, Gebitekin C. Case of solitary eosinophilic granuloma of the sternum. *Thorac Cardiovasc Surg* 2008;56:117–118
14. Biswas S, Keddington J. Soft right chest wall swelling simulating lipoma following motor vehicle accident: trans-diaphragmatic intercostal hernia. A case report and review of literature. *Hernia* 2008;12:539–543
15. Takamori S, Miwa K, Hayashi A, Shirouzu K. Intramuscular lipoma in the chest wall. *Eur J Cardiothorac Surg* 2004;26:1038

16. Ozpolat B, Ozeren M, Akkaya T, Yucel E. Giant lipoma of chest wall. *Eur J Cardiothorac Surg* 2004;26:437
17. Eren S, Avci A. Giant cystic lymphangioma in the thoracic wall in a newborn. *Asian Cardiovasc Thorac Ann* 2009;17:659
18. Yildirim E, Dural K, Kaplan T, Sakinci U. Cystic lymphangioma: report of two atypical cases. *Interact Cardiovasc Thorac Surg* 2004;3:63–65
19. Sakurai K, Hara M, Ozawa Y, Nakagawa M, Shibamoto Y. Thoracic hemangiomas: imaging via CT, MR, and PET along with pathologic correlation. *J Thorac Imaging* 2008;23:114–120
20. Griffio S, Stassano P, De Luca G, Di Tommaso L, Monaco M, Spiezia S. Intramuscular hemangioma of the chest wall: an unusual tumor. *J Thorac Cardiovasc Surg* 2007;134:1368–1369
21. Gallo AE, Coady MA. Chest wall tumors. In: Yuh DD, Vricella LA, Baumgartner WA eds. *The Johns Hopkins Manual of Cardiothoracic Surgery*. New York, NY: McGraw Hill; 2007:75–90
22. Bölke E, Krasniqi H, Lammering G, et al. Chest wall and intrathoracic desmoid tumors: surgical experience and review of the literature. *Eur J Med Res* 2009;14:240–243
23. Abbas AE, Deschamps C, Cassivi SD, et al. Chest-wall desmoid tumors: results of surgical intervention. *Ann Thorac Surg* 2004;78:1219–1223; discussion 1219–1223
24. Tateishi U, Gladish GW, Kusumoto M, et al. Chest wall tumors: radiologic findings and pathologic correlation: part 2. Malignant tumors. *Radiographics* 2003;23:1491–1508 Review
25. Stanić V, Vulović T, Novaković M, et al. Radical resection of giant chondrosarcoma of the anterior chest wall. *Vojnosanit Pregl* 2008;65:64–68
26. Somers J, Faber LP. Chondroma and chondrosarcoma. *Semin Thorac Cardiovasc Surg* 1999;11:270–277
27. Lee WS, Kim YH, Chee HK, et al. Multimodal treatment of primary extraskeletal Ewing's sarcoma of the chest wall: report of 2 cases. *Cancer Res Treat* 2009;41:108–112
28. Bousnina S, Zendah I, Marniche K, et al. Solitary plasmocytoma of the rib: a rare tumor not to miss. *Rev Pneumol Clin* 2006;62:243–246
29. Yoshida N, Miyanari N, Yamamoto Y, Egami H. Successful treatment of malignant fibrous histiocytoma originating in the chest wall: report of a case. *Surg Today* 2006;36:714–721
30. Shoji T, Sonobe M, Okubo K, Wada H, Bando T, Date H. Giant primary liposarcoma of the chest. *Gen Thorac Cardiovasc Surg* 2009;57:159–161
31. Styring E, Fernebro J, Jönsson PE, et al. Changing clinical presentation of angiosarcomas after breast cancer: from late tumors in edematous arms to earlier tumors on the thoracic wall. *Breast Cancer Res Treat* 2010;122:883–887
32. Schwarz RE, Burt M. Radiation-associated malignant tumors of the chest wall. *Ann Surg Oncol* 1996;3:387–392
33. Haraguchi S, Hioki M, Takushima M, Yanagimoto K, Koizumi K, Shimizu K. Metastatic chest wall tumor suspected to be of lung origin by immunoreactivity for cytokeratin 7 and 20. *Jpn J Thorac Cardiovasc Surg* 2006;54:132–136
34. Hazard HW, Gorla SR, Scholtens D, Kiel K, Gradishar WJ, Khan SA. Surgical resection of the primary tumor, chest wall control, and survival in women with metastatic breast cancer. *Cancer* 2008;113:2011–2019
35. La Quaglia MP. Chest wall tumors in childhood and adolescence. *Semin Pediatr Surg* 2008;17:173–180
36. Wyttenbach R, Vock P, Tschäppeler H. Cross-sectional imaging with CT and/or MRI of pediatric chest tumors. *Eur Radiol* 1998;8:1040–1046
37. van den Berg H, van Rijn RR, Merks JHM. Management of tumors of the chest wall in childhood: a review. *J Pediatr Hematol Oncol* 2008;30:214–221