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# Chest wall reconstruction after tumor resection

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ABSTRACT

Pediatric chest wall tumors are rare. Malignancies predominate of which sarcomas are the most common. Their resection and the subsequent reconstruction of the chest wall has been a surgical challenge since Dr. Frederick W. Parham published his first comprehensive account on the subject in 1898. Chest wall reconstruction is age, site and pathology dependent, must preserve long term function and cosmesis, must accommodate future growth and development, and must not be a hindrance to adjuvant radiotherapy. Bony reconstruction can be relatively simple or complex involving combinations of synthetic meshes, bioprosthetic materials, steel or titanium constructs, autografts, homografts and porcine or bovine xenografts. Soft tissue coverage can be achieved with direct closure, skin grafts, local advancement flaps, pedicled or free myocutaneous or osseomyocutaneous flaps or a combination of these. Complications to be avoided include scoliosis, pain and activity restriction, restrictive pulmonary deficits and interference with adjuvant radiotherapy which may result in tumor recurrence. Advances in cancer therapy have improved short- and long-term survival but significant functional and cosmetic challenges remain particularly for large chest wall defects in the very young. The future may lie with absorbable semi-rigid meshes, biointegratable acellular homografts and xenografts, demineralized bone matrices and bone marrow stromal cells, the patient's own lab-grown stem-cell based vascularized osseomyocutaneous chest wall grafts or the obsolescence of surgical resection altogether in the age of targeted anti-tumor and immune based therapy.



## Introduction

The first comprehensive account of tumor resection and reconstruction of the chest wall was penned by Dr. Frederick W. Parham in 1899 in "Thoracic Resection for Tumors Growing from the Bony Wall of the Chest". It was read in abstract form to the Southern Surgical and Gynecological Association in Memphis, Tennessee in November 1898. It meticulously documents 78 cases of chest wall resection, 52 of which involved entry into the pleural cavity – often with disastrous consequences. He described his use of a pectoral flap to cover a right chest wall defect resulting in a pneumothorax, following resection of the lateral aspects of the right 3rd, 4th and 5th rib for an osteosarcoma in a 27 year old woman.[1] This and the other cases described illustrate the pioneering efforts of surgeons who treated chest wall tumors without neoadjuvant or adjuvant therapy, anesthesia, antibiotics, critical care or sophisticated prosthetic materials. The youngest patient in his series was a 12 year-old girl with a sarcoma of the manubrium.

Pediatric chest wall tumors (CWT) are rare, accounting for only 1.8% of all childhood cancers.[2] Malignancies predominate and of these, sarcomas are most common. Approximately 55% are of bony or cartilaginous origin while the remaining 45% are soft tissue sarcomas. The most common malignant CWT of childhood is Ewing sarcoma, followed by rhabdomyosarcoma (both embryonal and alveolar subtypes), osteosarcoma, chondrosarcoma, fibrosarcoma, synovial sarcoma, and then a variety of other sarcomas.[3,4] Benign lesions include chondroma, osteoma, fibroma, lipoma, eosinophilic granuloma, aneurysmal bone cyst, fibrous dysplasia, hemangioma and mesenchymal hamartoma.[3]

Most children present with a painless mass, cough or pain. Other common presentations include an incidental finding on chest x-ray and respiratory difficulty due to intrathoracic extension and/or pleural effusion.[3] Some CWTs are sensitive to chemotherapy and/or radiotherapy and are treated neo-adjuvantly prior to resection. For those that are chemo and/or radio-resistant, up-font resection confers the best chance of cure.

Improvements in anesthesia, surgical technique and post-operative care have allowed for aggressive and extensive resections with excellent short term post-operative outcomes. However for large defects, the resulting long-term functional and cosmetic

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impairment has necessitated advances in reconstructive materials and techniques. Pediatric patients pose the additional challenge of future growth and development that must be accommodated by the reconstructive method. This article will outline the principles of surgical resection and reconstruction for CWTs and examine the different reconstructive techniques, their pitfalls and complications and their application to pediatric patients at various stages of development.

## Principles of surgical resection

Surgical resectability of CWTs is determined by the number of ribs involved, the degree of intra-pleural extension and involvement of mediastinal structures, invasion of the spinal canal, and the presence of locoregional and distant metastases. Resection techniques vary depending on the pathology and the location of the tumor – anterior, lateral or posterior. Prior to resection, cross-sectional imaging should be examined closely in order to define the extent of the tumor and planned resection. Any pleural effusion in the absence of other evidence of metastases should be aspirated for cytological analysis and if positive, may be an indication for adjuvant radiotherapy that will need to be accommodated by the reconstructive method. Ewing's sarcoma and rhabdomyosarcoma are usually chemosensitive and should be treated with neoadjuvant chemotherapy unless clearly resectable upfront.

In the operating room, under general anesthetic, the patient should be positioned such that the area to be resected is easily accessible. For posterior and lateral tumors the patient should be in the lateral position with the pathology uppermost. For anterior resections the patient should be supine. Prior to incision, the location of the tumor and the number of ribs involved should be marked on the patient's skin, as should the extent of dissection. The incision should be made over the tumor unless it involves skin in which case an elliptical incision should encompass the skin to be resected en-bloc with the tumor. This should include any prior core or incisional biopsy sites. If the tumor is not palpable externally, an incision between the ribs should be made which is clearly superior or inferior to the expected tumor to avoid inadvertent entry into the tumor itself. Then, by digital exam, it can be determined which ribs will require resection and where they should be divided. Superior and inferior subcutaneous flaps should be fashioned which extend widely enough to encompass the superior and inferior extent of the resection. A muscle sparing approach can be used, provided the muscle is free of involvement. Adherent myofascial layers should be removed en-bloc with the tumor. All areas of dense fibrotic scar should be removed as they may harbor small areas of microscopic disease. For malignant tumors, it is generally accepted that a 1 cm margin is required. The adage 'one rib above and one rib below' should be followed for all malignancies except for RMS for which overall survival for patients with positive and negative microscopic margins are equivalent following adjuvant radiotherapy; periosteum of the adjacent rib is an acceptable margin for RMS.[5] In larger patients, the width of the intercostal muscle may provide an adequate margin. For benign lesions, a 1 cm margin is not required. Frozen section analysis is not possible with any accuracy on bone or cartilage. The chest cavity should be entered via the rib space at the resection margin. By palpation and visualization, the anterior and posterior extent of rib resection should be assessed. At the posterior extent of the tumor, the intercostal arteries and veins should be ligated. Then the rib and intercostal muscle should be divided. The same should be done at the anterior extent. If a posterior rib disarticulation is required, a spinal surgeon should be consulted. 'Pulling' on the rib posteriorly or improper technique may result in hemorrhage into the spinal canal and paralysis. First rib resections should be done by an experienced team to avoid damage to the brachial plexus.

The entire length of an involved rib is rarely resected, with the exception of Ewing sarcoma in which medullary extension or metastasis may occur. MRI evaluation for intra-medullary tumor extension must be conducted prior to neoadjuvant treatment and all involved areas of the rib should be resected or radiated to achieve local control.

Malignant tumors frequently expand into the chest cavity prior to presentation as an external mass. Therefore pleural and/or lung involvement should be anticipated. If the lung is 'stuck' to the chest wall tumor, it should not be separated as breaching the tumor capsule may result in seeding of the pleural cavity. Involved lung and diaphragm should be resected en-bloc with the involved chest wall. In most cases, primary repair of the diaphragm is possible. Direct extension of the tumor onto the visceral or parietal pleura does not preclude surgical resection. If pleural lesions are noted distinct from the primary site they should be biopsied to define the presence of local spread of the tumor at presentation and/or to evaluate for residual viable tumor following neoadjuvant therapy. Pleural metastasis persistent after chemotherapy should be assessed for resection and/or post-operative radiotherapy. Spinal cord or spinal canal involvement precludes complete resection with a margin of normal tissue and is an indication for primary radiotherapy.

Following resection, the specimen must be oriented with areas of interest defined by sutures or clips. Inviting the pathologist to the operating room at the time of specimen orientation increases the accuracy of their evaluation. Radiotherapy will be required in the event of positive margins, unresectable intrathoracic metastases and/or positive cytology on pleural fluid or washings.

## Principles of surgical reconstruction

Reconstruction has two components – 1. Skeletal reconstruction, and 2. Soft tissue coverage.[6] The objectives of chest wall reconstruction include the restoration of chest wall rigidity and protection of the underlying organs, prevention of pulmonary or cardiac herniation, preservation of respiratory function, avoidance of scapular trapping, an acceptable cosmetic outcome, accommodation of growth and development, and facilitation of adjuvant radiotherapy if required. The indications for reconstruction include resection of $\geq$4 ribs, defects $\geq$5 cm, and anterior costal and sternal resections. This is particularly true for full-thickness chest wall resections. Resections beneath the pectoral muscles do not require reconstruction. The same is true for sub–scapular resections unless there is a risk for scapula trapping on adduction of the shoulder from an abducted position.[7]

Chest wall reconstruction can be complex and involve mesh and/or myocutaneous flaps. Materials available for chest wall reconstruction include synthetic meshes, bioprosthetic materials, stainless-steel bars, osseo-integrated titanium systems, autografts, homografts and porcine or bovine xenografts. Soft tissue coverage is usually achieved by primary closure, or local or free myocutaneous flaps with the help of plastic and reconstructive surgical teams. The key to chest wall reconstruction is creativity and flexibility. The construction should be tailored to the individual patient's needs and often requires integration of more than one reconstructive method. Whatever the technique employed, consideration for future growth and development of the pediatric patient is a major consideration.

## Methods of reconstruction

The ideal material for chest wall reconstruction is malleable enough to conform to the shape of the chest wall, rigid enough to prevent paradoxical motion and protect intrathoracic organs,