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Chest Wall Reconstruction in Pediatric Patients with Chest Wall Tumors: A Systematic Review

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Title: Chest Wall Reconstruction in Pediatric Patients with Chest Wall Tumors: A Systematic Review

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ABSTRACT

Background: Resection of pediatric chest wall tumors can result in large defects requiring reconstruction for function and cosmesis. Multiple reconstructive methods have been described. We performed a systematic review of the literature to describe commonly used approaches and outcomes.

Methods: A systematic literature search was performed for English-language publications describing chest wall tumor resection and reconstruction using implantable materials in patients ≤21 years, excluding soft tissue resection only, sternal resection, and reconstruction by primary repair or muscle flaps alone. Data were collected on diagnoses, reconstructive method, and outcomes. Rigid chest wall reconstruction was compared to mesh reconstruction.

Results: There were 55 articles with 188 patients included. The median age was 12 years. Most tumors were malignant (n=172, 91.5%), most commonly Ewing's sarcoma (n=65, 34.6%), followed by unspecified sarcomas (n=34, 18.1%), Askin's tumor (n=16, 8.5%; a subset of Ewing's sarcoma) and osteosarcoma (n=16, 8.5%). A median of 3 ribs were resected (range 1-12). Non-rigid meshes were most common (n=138, 73.4%), followed by rigid prostheses (n=50, 26.6%). There were 19 post-operative complications (16.8%) and 22.2% of patients developed scoliosis. There were no significant differences in complications (20.5% rigid vs. 10.6% non-rigid, p=0.18) or scoliosis (22.7% vs. 14.0%, p=0.23) by reconstruction method, but complications after rigid reconstruction were more likely to require surgery (90.0% vs. 53.9%, p=0.09). The median follow-up duration was 24 months.

Conclusions: In this review of the literature, there were no significant differences in overall post-operative complications or scoliosis development by reconstruction method, yet complications after rigid reconstruction were significantly more likely to require surgical intervention.

Keywords: pediatric surgical oncology; chest wall tumors; chest wall reconstruction

Level of Evidence: Level IV

Introduction

Primary chest wall tumors (CWT) are rare, comprising 1%-2% of all primary tumors [1]. CWT can be primary or metastatic, malignant or benign, and may arise from the soft tissue or bony structures of the chest wall. In children, primary CWT most commonly arise from the ribs [1,2]. The most common type of malignant CWT in children are Ewing's sarcomas, occurring most frequently during the second decade of life [3]. Overall survival depends on histology, stage, tumor location and surgical margins. For many tumors, a wide surgical margin is critical to optimize outcomes, yet large surgical resections pose unique challenges in the pediatric population given the need to accommodate future growth and development.

Pediatric chest wall reconstruction techniques involve reconstructing the skeletal component of the chest wall to provide sufficient rigidity for function, as well as providing adequate tissue coverage. Chest wall reconstruction must restore chest wall rigidity, protect underlying organs, prevent herniation, preserve respiratory function, and provide acceptable cosmetic outcomes all while allowing for sufficient growth capacity of the developing child or adolescent [4]. An optimal chest wall reconstruction material would ideally avoid potentially long-term sequelae including the development of scoliosis or restrictive lung disease. Depending on the location of the tumor, the reconstructive needs may vary. Common reconstructive materials include Gore-Tex® patches, Marlex® mesh, and vicryl patches; however, more rigid adjuncts such as Marlex® mesh-methyl methacrylate sandwich techniques or the STRATOS™ titanium system, among others, are also used to provide increased structure to the chest wall [5–8]. Materials should be rigid enough to provide stability, prevent flail chest or paradoxical motion, and protect intrathoracic structures, yet the ideal reconstruction material would also allow for ongoing growth and development. Additional material challenges are that radio-

opaque material may interfere with future imaging and surveillance as well as adjuvant radiotherapy.

While the ideal reconstruction material must be tailored to each individual patient, there is a lack of clear, evidence-based guidelines on the most appropriate reconstructive material for chest wall tumors in pediatric populations. Furthermore, little is known about the long-term outcomes and complications of these materials in pediatric patients undergoing CWT reconstruction. While several studies have focused on the efficacy and safety of reconstructive techniques after resection of chest wall tumors[9,10], few solely focus on the pediatric population and even fewer on patient outcomes by reconstruction material.

This systematic review aims to provide a detailed comparison of common reconstruction materials and patient outcomes following chest wall resection in pediatric patients with chest wall tumors by examining the current approaches and their associated postoperative complications and outcomes. Examining the current approaches and their associated postoperative complications and development of scoliosis may provide insight on the optimal chest wall reconstructive material in children and adolescents.

Methods

Literature Search

With the assistance of a reference librarian, a systematic literature search of PubMed, Web of Science, Embase, and Google Scholar was performed by two authors to identify English-language publications describing chest wall tumor resection and reconstruction using implantable materials in patients ≤ 21 years old through March 2020. The key words used for the search terms included chest wall reconstruction, thoracic reconstruction, pediatrics, and thoracic or

chest wall tumors. No other filters, including publication date range, were employed. No attempts were made to obtain information from unpublished studies. The protocol utilized is based on the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) checklist for reporting of systematic reviews. A full description of the search terms utilized is available in **Supplemental Digital Content 1: Systematic Review Search Strategy.** Publications of any type, including case reports and series, prospective observational studies, and randomized controlled trials were eligible for inclusion. Abstracts of all studies were screened independently by two investigators using the Covidence software tool (Covidence, Veritas Health Innovation, Melbourne, Australia). The article full texts were independently screened by two reviewers. Conflicts were resolved by consensus to create the final list of included studies. Inclusion criteria were English-language publications describing chest wall resection and reconstruction with implantable materials for benign or malignant tumors or chest wall growths in patients ≤ 21 years old. Exclusion criteria were patients > 21 years old, non-English language articles, chest wall reconstruction for non-tumor etiologies including trauma and congenital anomalies, cases of soft tissue resection only with no chest wall resection, sternal resection, and reconstruction without the use of implantable materials such as primary chest wall repair or muscle flaps. Articles were additionally excluded if pediatric patients were not described separately from adult patients.

Data Extraction

Data extracted from the final list of articles included study design, year of publication, country of publication, number of patients included, demographics, tumor etiology, benign or malignant tumor, tumor location, use of neoadjuvant or adjuvant chemotherapy or radiation, type

of surgical resection performed, reconstruction material used, post-operative complications, and development of scoliosis, post-operative pulmonary function, and duration of follow-up. Reconstructive material was categorized as rigid or non-rigid. Rigid materials included the following rigid prosthetics: Lactosorb®, rib replacement struts (BioBridge), STRATOS™ system, Vertical Expandable Prosthetic Titanium Rib (VEPTR), polyetheretherketone (PEEK) implants, three dimensional printed implants, mesh-methyl methacrylate, and titanium plates. Non-rigid materials included any synthetic or biologic mesh. Patients who underwent combined reconstruction with rigid and non-rigid materials were classified as undergoing rigid reconstruction. Complications were graded on a scale of 1-4 modeled after a study by Smith *et. al*, with modifications to more accurately describe the complications observed in this review [11]. Grade 1 complications required medical or procedural treatment without requiring a return to the operating room. Grade 2 complications resulted in an unplanned return to the operating room. Grade 3 complications refer to substantial post-operative complications which significantly altered the course of recovery.

Data Analysis

Descriptive statistics were performed. Continuous data are presented as median and interquartile range (IQR) and categorical data are presented as number and percentage. The number of publications with missing data for any given variable are reported and the denominators utilized are number of publications with such data reported and available for analysis. Results were compared between patients who underwent reconstruction with rigid materials and those who underwent reconstruction with mesh by χ^2 or Fisher's exact test, where

appropriate. Statistical significance was set at $p < 0.05$. Analyses were performed using statistical software (Prism for Mac, version 9.00; GraphPad software, San Diego, California).

Results

Article Selection

A total of 467 articles were analyzed for inclusion after systematic database searches. After removing duplicates (n = 44), 423 articles underwent abstract screening. 260 articles were excluded and 155 full-text articles were subsequently screened for inclusion. 100 articles were excluded. A total of 55 articles reporting on 188 cases of pediatric chest wall tumor resection and reconstruction were included (**Figure 1**). The full list of included citations is available in **Supplemental Table 1**.

Article Characteristics

The first included article was published in 1960 and reported on a single case of an 8-year-old boy who underwent chest wall reconstruction with Marlex mesh after resection of an unspecified sarcoma [6]. Following that, the number of publications increased in the subsequent decades, with 32 publications between 2010-2020 reporting on 111 patients (**Figure 2**). Most publications were single-institution case series (n = 40/55, 71.7%), and the remaining 15 articles were case reports (27.3%). There were no prospective or randomized studies.

Patient Characteristics

The median age was 12 years old (IQR 7-16, range newborn-21 years old). Of studies reporting sex, the majority of patients were male (n = 83/144, 58.3%). Most tumors were

malignant (n = 172, 91.5%) with the most common diagnosis being Ewing's sarcoma (n=65, 34.6%), followed by unspecified sarcomas (n=34, 18.1%), Askin's tumor (a subset of Ewing's sarcoma) (n=16, 8.5%) and osteosarcoma (n=16, 8.5%) (**Table 1**).

Neoadjuvant and/or adjuvant chemoradiation

For patients with malignant tumors (n=172), data on utilization of neoadjuvant chemotherapy or radiation therapy was available for 110 patients. Of these, the majority (n = 90/110, 81.8%) received either chemotherapy or radiation pre-operatively. Fifteen patients received neoadjuvant chemoradiation (15/90, 16.7%), 69 received pre-operative chemotherapy only (69/90, 76.7%), and five underwent pre-operative radiation therapy only (5/90, 5.6%). Data regarding the use of adjuvant chemotherapy or radiation therapy was reported in 98 patients. Of these, the majority (n=76/98, 77.6%) underwent some form of adjuvant therapy. This was most commonly adjuvant chemotherapy alone (n = 45/98, 45.9%). Twenty-seven patients (n = 28/98, 28.6%) underwent adjuvant chemoradiation, while two patients had isolated adjuvant radiation.

Surgical procedures

All included patients underwent resection of the chest wall tumor. The number of ribs resected was reported in 131 cases, with a median of 3 ribs resected (range 1-12 ribs). Rigid reconstructive materials were used in 50 patients (26.6%) and included rigid fixation systems (STRATOS™, PEEK implants, and rib molds) in 4 patients, rigid biodegradable systems (Lactosorb®, BioBridge, and polylactic acid struts) in 11 patients, and unspecified rigid rib prostheses in 2 patients (**Table 2**). Titanium prostheses were used in 5 patients. Rigid

reconstruction techniques also included a combination of rigid and non-rigid materials used in 27 patients; these included combinations of Gore-Tex® and STRATOS™, titanium rib prostheses or plates, and VEPTR; alloderm and VEPTR; extracellular matrix and Synthes bars; Tutopatch® and STRATOS™, prolene mesh combined with dynamic compression plates. The most common combination involved a Marlex mesh and methyl methacrylate sandwich technique (15/27 patients).

Non-rigid reconstructive materials were used in 138 cases (73.4%). These were most commonly synthetic meshes (n = 111/138, 80.4%), primarily Gore-Tex® (n = 58) or Marlex (n = 26). Less commonly used synthetic meshes are included in **Table 2**. Biologic materials were used in 27 patients (14.4%), including Veritas matrix, Biodesign®, Tutomesh®, acellular dermal matrix, Surgisis®, Strattice Tissue Matrix™, dura, Permacol™, and alloderm. Patients undergoing rigid reconstruction had a median of 3 ribs resected (IQR 3-4), as did patients undergoing non-rigid reconstruction (IQR 3-3.25, p = 0.2). Patients undergoing rigid reconstruction were older (median age 14 vs. 11 years old for non-rigid, p = 0.02).

Complications

Post-operative complications were discussed in 40 studies that included a total 137 patients (72.9%). Of these 137 patients, 23 patients had a post-operative complication (16.8%). In patients who underwent repair with rigid materials, post-op complications occurred in 10 of 44 who had this outcome discussed (22.7%). These included dislocated titanium bars requiring surgical intervention (n = 1) [12], titanium wire fracturs (n = 2, one requiring surgical removal) [13], a fractured Marlex-methyl methacrylate plate requiring repair (n = 1) [14], a seroma requiring aspiration (n = 1) [8], a surgical site infection requiring prosthesis removal of methyl

methacrylate (n = 1) [7], skin flap necrosis (n = 1) [15], puncture of the subclavian artery by a titanium plate (n = 1) [16], and one unspecified complication which required surgical intervention (n = 1). In patients who underwent reconstruction with non-rigid materials, post-operative complications occurred in 13 of the 93 patients who had this outcome discussed (14.0%). These included seromas (n = 2), surgical site infections (n = 2), abdominal wall paresis (n = 1) [17], respiratory failure following resection of substantial intrathoracic disease burden complicated by ventilator-acquired pneumonia, which resolved after antibiotic treatment over 6 weeks without need for tracheostomy (n = 1) [18,19], bronchopleural fistula after pneumonectomy for underlying disease at time of reconstruction (n = 1) , dislocation of a remnant rib from mesh (n = 1) [20], pulmonary edema, pleural effusion, and restrictive lung disease (n = 1) [21], development of flail segment requiring BiPAP and an incisional wound vacuum device which resolved by the fourth post-operative day (n = 1) [22,23], and three unspecified post-operative complications (n = 3). Post-operative complications were two times more common in patients undergoing rigid reconstruction, but this difference was not statistically significant (22.7% vs. 14.0%, p = 0.23). Of note, complications from rigid materials were more often associated with a need for a second procedure (9/10 or 90.0% of complications within rigid group vs. 7/13 or 53.9% of complications within non-rigid group, p = 0.09). On our severity grading scale, the median severity was 2 (complications requiring unplanned return to the operating room, 52.2%). One-third of complications were severity grade 1 (complications requiring medical or procedural treatment, 34.8%), and three patients sustained grade 3 complications (13.0%). No patients died as a result of reconstruction-related complications. There was no significant difference in the severity of complications by type of reconstruction (rigid cohort median severity 2 vs. non-rigid cohort median severity 1, p = 0.35).

Assessing long-term outcomes, development of scoliosis was discussed in 29 studies that included a total of 126 patients (67.0%) and occurred in 28 patients (28/126, 22.2%). Among patients who underwent rigid reconstruction, scoliosis developed in 8 patients of 32 cases in which this outcome was reported (25.0%). The outcome of scoliosis was reported in 94 patients who underwent non-rigid reconstruction and occurred in 20 of these patients (20/94, 21.3%). Rates of scoliosis did not differ significantly between cohorts ($p = 0.63$). Patients who developed scoliosis had a higher number of ribs resected than those who did not (median 4 ribs vs. 3 ribs, $p = 0.04$).

Post-operative pulmonary function was reported in four studies. In an early study of 8 patients undergoing reconstruction with synthetic mesh by Malangoni *et. al.,* patients had a reduction in their forced vital capacity (FVC, ranging from 31-74% of predicted values) with normal FEV_1 (forced expiratory volume) to FVC ratio, indicative of restrictive lung disease [24]. They noted that this level of restrictive lung disease persisted but did not worsen over time. A second study by Grosfeld *et. al.* of patients reconstructed with synthetic mesh noted early evidence of restrictive lung disease with reduced FVC which progressed in all patients [23]. A third study by Marqués *et. al.* reported that the four included patients who underwent reconstruction with synthetic mesh had low FVC and FEV_1 values which did not change over time [25]. The final study which discussed pulmonary function only reported that one patient reconstructed with synthetic mesh developed restrictive lung disease [21].

The duration of follow up was reported in 112 cases, and the median follow up duration was 24 months (range 2 months – 15 years). Survival outcomes were reported in 150 patients; the overall mortality was 18.0% (n = 27/150), with the majority of deaths due to their underlying malignancy, recurrence, or metastases (22/27, 81.5%). One patient died from a second

malignancy which developed 11 years later [23]. One patient died of pulmonary fibrosis due to a bronchopleural fistula; one from respiratory failure [26]; one from sepsis [19]; and one from meningitis with no evidence of disease [23].

Discussion

In this systematic review assessing chest wall reconstruction techniques in pediatric patients with chest wall tumors, we found that non-rigid reconstructive materials were most commonly used and that the most common non-rigid reconstructive materials were Gore-Tex® and Marlex mesh. Rigid reconstruction materials were used about one quarter of the time and most often utilized a combination of Marlex mesh and methyl methacrylate, followed by Lactosorb®, a rigid biodegradable system. It is important to note that there was no significant difference in median number of ribs resected in either group. While there was no significant difference in complication rates between patients undergoing rigid or non-rigid reconstruction (22.7% of patients undergoing rigid reconstruction vs. 14.0% of patients undergoing non-rigid reconstruction, $p = 0.23$), almost a quarter of patients who underwent rigid reconstruction experienced a complication and 90% of patients developing a complication after rigid reconstruction required an additional procedure. This high rate of secondary surgical intervention was significantly different compared to those with non-rigid reconstruction. Lastly, scoliosis developed in 22.2% of patients overall without a significant difference in outcomes between reconstructive materials (25.0% of rigid reconstructions vs. 21.3% of non-rigid reconstructions, $p = 0.63$), however those developing scoliosis had a higher number of ribs resected (4 vs. 3, $p = 0.04$).

Pediatric chest wall tumors are rare and challenging cases that often require complex reconstruction following resection. There are several goals of chest wall reconstruction, including adequate functional and cosmetic outcomes, as well as consideration of long-term outcomes as the child grows. The optimal reconstructive material is unknown and data regarding long-term outcomes is limited [4]. Options include flexible synthetic and biologic meshes, which are malleable, but may not provide the stability required for large reconstructions [4]. Rigid reconstructive materials may be used to provide additional chest wall stability for larger defects [11] and are often used in combination with pliable meshes [13]. A number of novel rigid options are available, including rigid rib fixation systems such as STRATOS™ [12] and the use of three-dimensional printing to create individualized reconstruction materials. However, there are some notable downsides to rigid materials as demonstrated in this review. The majority of the complications noted in the rigid reconstruction group were related to failure of the rigid implants, and the consequences of these complications are significant and 90% of reported complications required additional surgical procedures such as the removal or replacement of the prosthesis [12–14]. Although rare, life-threatening complications such as arterial injury were also reported [16]. Rigid mesh options such as the Marlex mesh with methyl methacrylate technique avoids metal implants and allows for stability of the chest wall but remains at risk of infection similar to other synthetic mesh options [7]. In our review, there were four total patients who developed a surgical site infection; two patients who underwent reconstruction with Gore-Tex®, one with dura, and one with methyl methacrylate. Thus, 75% of post-operative infections occurred in patients undergoing repair with synthetic or rigid materials, but due to the overall rare incidence of infections, it is not possible to state that the type of material is associated with the development of an infection. Notably, a limitation of many rigid prosthetics is their

radiopaque nature which may limit adjuvant radiotherapy and surveillance. Furthermore, their ability to accommodate future growth of a developing child is limited, a critical consideration in younger pediatric patients, and it is important to note that children who underwent rigid reconstruction were significantly older than those who underwent non-rigid repair.

Biologic meshes are an alternative to synthetic meshes with a lower risk of infection, but are still subject to post-operative complications such as seroma formation, and provide less stability compared to both rigid prosthetics and even synthetic mesh materials [17–19,27]. In this systematic review of the literature, we found no significant difference in post-operative complication rates by type of reconstructive material, although twice as many patients undergoing reconstruction with rigid materials had post-operative complications. Some concerning post-operative complications were noted in the non-rigid cohort, including a patient who developed flail chest, and one must consider the possibility of this complication when choosing a non-rigid reconstructive material. One of the main long-term potential adverse sequalae of pediatric chest wall reconstruction is the development of scoliosis. In one study of forty children undergoing chest wall resection for tumors, 42.5% developed scoliosis. Remarkably, 80% of patients under the age of six years old at the time of resection developed scoliosis [28]. Resection of three or more ribs was associated with an 18.9-times increased odds of scoliosis [28]. These rates are higher than those noted in this systematic review, with 22.2% of patients developing scoliosis; however, this outcome was only reported in 67.0% of patients, and the true incidence of scoliosis may be higher. Additionally, the median follow-up duration was only 24 months, and thus scoliosis may have developed later in some patients and is a limitation of the relatively short follow-up for the included studies. Lastly, the development of scoliosis is a multifactorial process, and younger age of patients, number of ribs resected, and posterior ribs

compared to anterior or lateral rib resection have all been associated with scoliosis development [14,28,29]. In the current review, there was no effect of the type of reconstructive material on this outcome, but a higher number of resected ribs was associated with scoliosis development.

Research is ongoing in the quest for the optimal reconstructive material following chest wall resection in pediatric patients. The material must be able to mold to the shape of the excised chest wall, allow for long-term chest wall stability, and ideally would grow with the child [4]. In older children and adolescents who have mostly finished growing, rigid reconstructive materials may be better suited than malleable mesh materials, but impact on adjuvant radiotherapy and future surveillance imaging is an important consideration. In younger children, absorbable or biologic materials may be ideal, as they may allow for ingrowth of native tissue and may allow for more flexibility as the child grows. However, providing adequate stability is a key component of a successful reconstruction and may not be sufficient with absorbable materials. Ultimately, these rare and challenging cases require an individualized and multi-disciplinary team to determine the optimal reconstruction technique for children with CWT requiring large resections. Advances in bioengineering and technology such as three-dimensional printing capabilities may provide much-needed avenue to achieve a more ideal reconstruction material. Tissue engineering, such as that incorporating mesenchymal stromal cells, is a promising avenue of innovation for the regeneration of bony and cartilaginous tissue [30]. As further studies are conducted in this field, it is important to note the paucity of data regarding functional pulmonary outcomes in these patients. In this review of 55 studies, only four obtained or described pulmonary function tests as a physiologic outcome of interest and none discussed thoracic insufficiency syndrome as an outcome. Further data on the impact of reconstructive chest wall

materials on pulmonary function over time will be critical in determining the optimal reconstructive material for the growing child.

Conclusion

There are no compelling data to support chest wall reconstruction with rigid materials in comparison to non-rigid materials. While reconstruction with rigid materials was significantly associated with higher rates of complications requiring secondary procedures, interstudy heterogeneity and a lack of high-quality, randomized studies limited analysis and the strength of recommendations. Surgical reconstruction after chest wall resection is complex and should be tailored to the needs of each individual case in order to optimize outcomes. MODERATE RECOMMENDATION, LOW QUALITY EVIDENCE.

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Fig. 1: PRISMA Diagram of article inclusion and exclusion.

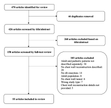
Fig. 2: Trends in publication on pediatric chest wall reconstruction over time. Bars represent the number of publications per decade, on the right y-axis; line represents the number of patients reported per decade, on the left y-axis.

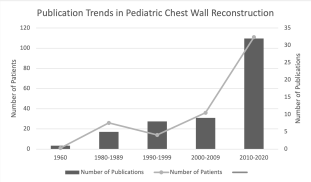
Table 1: Tumor etiologies

Tumor type	Number of patients, n (%) n = 188
Malignant	172 (91.5)
Ewing's sarcoma	65 (34.6)
Sarcoma, unspecified subtype	34 (18.1)
Askin's tumor	16 (8.5)
Osteosarcoma	16 (8.5)
Primitive neuroectodermal tumor	8 (4.3)
Rhabdomyosarcoma	5 (2.7)
Malignant small round cell tumor	4 (2.1)
Synovial sarcoma	4 (2.1)
Chondrosarcoma	3 (1.6)
Neuroblastoma	2 (1.1)
Metastases from other tumors	2 (1.1)
Angiosarcoma	1 (0.5)
Desmoid tumor	1 (0.5)
Epithelioid sarcoma	1 (0.5)
High-grade undifferentiated sarcoma	1 (0.5)
Infantile fibrosarcoma	1 (0.5)
Langerhans cell histiocytosis	1 (0.5)
Lymphoma	1 (0.5)
Malignant mesenchymoma	1 (0.5)
Pleuropulmonary blastoma	1 (0.5)
Primitive myxoid mesenchymal tumor	1 (0.5)
Schwannoma	1 (0.5)
Spindle cell tumor	1 (0.5)
Wilms tumor	1 (0.5)
Benign	16 (8.5)
Mesenchymoma/hamartoma	4 (2.1)
Lipoblastoma	2 (1.1)
Intercostal hemangioma	2 (1.1)
Aneurysmal bone cyst	2 (1.1)
Vascular malformation	2 (1.1)
Fibrous dysplasia	1 (0.5)
Myofibroblastoma	1 (0.5)
Osteochondroma	1 (0.5)
Thoracic lymphangiomatosis	1 (0.5)

Table 2: Types of reconstructive materials used

Type of reconstruction	Number of patients
Rigid	50
Marlex and methyl methacrylate	15
Lactosorb®	10
Titanium prostheses	5
STRATOS™ and Gore-Tex® patch	4
VEPTR and Gore-Tex®	3
Rib-like prosthesis/mold	3
Titanium plates and Gore-Tex®	2
PEEK implant	2
VEPTR and alloderm	1
STRATOS™ bar and Tutopatch®	1
Dynamic compression plates and Prolene mesh	1
Synthes bars and extracellular matrix	1
STRATOS™ bars	1
BioBridge struts	1
Non-rigid	138
Synthetic meshes	111
Gore-Tex®	58
Marlex	26
Vicryl mesh	6
Gore-Tex and Vicryl mesh	4
Prolene mesh	3
Neuro-patch	3
Dacron patch	2
Dexon mesh	2
Teflon mesh	2
Gore-Tex® and Marlex	1
Polyethylene knitted mesh	1
Polypropylene mesh	1
Surgimend®	1
Not specified	1
Biologic meshes	27
Biodesign®	7
Dura	6
Permacol™	5
Surgisis®	3
Strattice Tissue matrix™	2
Alloderm	1
Acellular dermal matrix	1
Tutomesh®	1
Veritas matrix	1





Highlights:

- There are multiple surgical approaches to pediatric chest wall tumor resection and reconstruction.
- Post-operative complications and development of scoliosis do not differ by reconstruction method (rigid or non-rigid).