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A Twelve-Year Consecutive Case Experience in Thoracic Reconstruction

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Background: We describe the second largest contemporary series of flaps used in thoracic reconstruction.
Methods: A retrospective review of patients undergoing thoracomyoplasty from 2001 to 2013 was conducted. Ninety-one consecutive patients were identified.
Results: Thoracomyoplasty was performed for 67 patients with intrathoracic indications and 24 patients with chest wall defects. Malignancy and infection were the most common indications for reconstruction ($P < 0.01$). The latissimus dorsi (LD), pectoralis major, and serratus anterior muscle flaps remained the workhorses of reconstruction (LD and pectoralis major: 64% flaps in chest wall reconstruction; LD and serratus anterior: 85% of flaps in intrathoracic indication). Only 12% of patients required mesh. Only 6% of patients with <2 ribs resected required mesh when compared with 24% with 3–4 ribs, and 100% with 5 or more ribs resected ($P < 0.01$). Increased rib resections required in chest wall reconstruction resulted in a longer hospital stay ($P < 0.01$). Total comorbidities and complications were related to length of stay only in intrathoracic indication ($P < 0.01$). Average intubation time was significantly higher in patients undergoing intrathoracic indication (5.51 days) than chest wall reconstruction (0.04 days), $P < 0.05$. Average hospital stay was significantly higher in patients undergoing intrathoracic indication (23 days) than chest wall reconstruction (12 days), $P < 0.05$. One-year survival was most poor for intrathoracic indication (59%) versus chest wall reconstruction (83%), $P = 0.0048$.
Conclusion: Thoracic reconstruction remains a safe and successful intervention that reliably treats complex and challenging problems, allowing more complex thoracic surgery problems to be salvaged. *(Plast Reconstr Surg Glob Open 2016;4:e638; doi: 10.1097/GOX.0000000000000603; Published online 17 March 2016.)*

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Chest wall reconstruction first evolved as a tool to reconstruct mastectomy defects. Halsted described skin graft closure and healing by secondary intention for chest wall defects in 1882.[1] Iginio Tansini is credited with describing the first regional muscle flap for chest wall reconstruction in 1896.[2] Kanavel advocated for the use of muscle in chest wall reconstruction and described the use of the latissimus dorsi (LD) muscle to obliterate an empyema chest cavity.[1] Fast-forwarding to the current era, Arnold and Pairolero[3] have described the use of

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several flaps for chest wall reconstruction including omentum, external oblique, pectoralis major (PM), and LD muscle flaps. Frequent indications for chest wall reconstruction include repair of traumatic injury, infection, reconstruction after tumor ablation, and treatment of the unfavorable sequelae of tumor management by radiation therapy.[3]

In this article, we describe the second-largest reported contemporary series of flaps used for thoracic reconstruction.[3–16] In addition, indications for thoracic reconstruction, perioperative considerations, evolution of operative techniques, and long-term outcomes are presented. The purpose of this study was to further characterize the clinical course for patients undergoing thoracic reconstruction. Anticipating a patient's hospital course and discharge date in this current era may help improve patient satisfaction, streamline health-care delivery, and assist in meeting guidelines, particularly for Medicare participating hospitals.

PATIENTS AND METHODS

An Institutional Review Board exempt retrospective chart review was performed for all patients, of all ages, who underwent thoracomyoplasty from 2001 to 2013 at the University of Wisconsin, Madison. Searching operating room (OR) records using the terms thoracotomy, muscle flap, or the corresponding CPT codes identified 98 consecutive patients. Seven patients were excluded because a cardiothoracic surgeon performed their thoracic reconstruction. Patients' charts were retrospectively reviewed for age, sex, medical history and comorbidities, body mass index (BMI), surgical history, thoracic procedure, generated anatomic defect, number of ribs resected, and surgical reconstruction technique. In-hospital and postoperative outcomes were reviewed including length of stay (LOS) and complications including prolonged intensive care unit stay, pneumonia, return to the OR, and mortality.

Statistical Analysis

Statistical analysis was performed by a PhD biostatistician. Categorical variables were summarized by reporting percentages and compared between groups using a two-tailed Fisher exact test. Means were estimated for continuous variables and compared between groups using analysis of variance. Pearson correlation coefficients were used to describe the relationship between 2 continuous variables. Patient survival was estimated utilizing the methods of Kaplan and Meier and compared between groups using a log-rank test. The impact of continuous variables on survival was evaluated using Cox proportional hazards models. Multivariable analysis was performed for patient survival, complications, and LOS based on patient type and all variables significant from univariate models. An a priori value of $P < 0.05$ was considered significant in all statistical analyses.

RESULTS

Between July, 2001, and December, 2013, 91 consecutive patients were identified who underwent thoracomyoplasty by the plastic surgery service in 2 distinct groups at the University of Wisconsin, Madison. Sixty-seven patients underwent thoracomyoplasty for intrathoracic indications and 24 patients for chest wall defects. Sixty-one (67%) were male, and 30 patients (33%) were female. Men made up the majority of intrathoracic patients (72%) and accounted for 54% of chest wall reconstruction patients ($P = 0.06$). The average age was 59 years (range, 28–83 years). The number of comorbidities averaged 2.0±1.5 (range, 0–7). The average BMI was 26.4±5.4 (range, 15–49) kg/m^2. The average BMI for patients undergoing chest wall reconstruction (28.7±5.6) was significantly higher ($P < 0.05$) than for patients undergoing intrathoracic reconstruction (25.7±5.2; Table 1).

Indications for surgery included infection (58%) and malignancy (32%), as well the presence of a fistula (Table 2). Many patients presented with more than 1 diagnosis. Intrathoracic reconstruction was more likely in the setting of infection, whereas chest wall reconstruction was more likely in malignancy ($P<0.01$). Chest wall reconstruction was more likely to be in the setting of recurrence when compared

Table 1. Patient Factors

Patient Factors	Intrathoracic	Chest Wall	Total	*P*
No. of patients (%)	67 (74)	24 (26)	91 (100)	
Age (yr)	61±12	56±13	59±13	0.09
No. of male (%)	48 (79)	13 (21)	61 (100)	
No. of female (%)	19 (63)	11 (37)	30 (100)	
Proportion of group male, %	72	54	67	0.06
BMI (kg/m^2)	25.7±5.1	28.7±5.6	26.4±5.4	<0.05
Average No. of comorbidities	2.1±1.5	1.8±1.5	2.0±1.5	
Number with >3 comorbidities (%)	22 (33)	8 (33)	30 (33)	

Table 2. Indications for Flap Coverage

Indications for Flap Coverage	Chest Wall	Intrathoracic	Total
Infection			
Empyema	2	40	42
Sternal wound	1	0	1
Aspergillosis	0	9	9
Osteomyelitis	1	0	1
Malignancy			
Large tumor	5	8	13
Recurrence	12	3	15
Previous radiation	0	2	2
Other			
Bronchopleural fistula	0	3	3
Bronchogastric fistula	0	1	1
Anastomotic leak	0	2	2
Exposed hardware	2	0	2
Osteoradionecrosis	1	0	1
Total	24	68	92

*Indications for intrathoracic reconstruction were more likely in the setting of infection ($P < 0.0001$).
†Indications for chest wall reconstruction were more likely in the setting of malignancy ($P < 0.01$).

Table 3. Flaps Used for Thoracic Reconstruction

Flap Type	Intrathoracic	Chest Wall	Total No. of Flaps
PM (%)	10 (9)	15 (32)	25 (15)
LD (%)	49 (42)	15 (32)	64 (39)
SA (%)	50 (43)	6 (13)	56 (34)
Rectus abdominis (%)	1 (1)	4 (9)	5 (3)
External oblique (%)	0 (0)	1 (2)	1 (1)
Paraspinal (%)	0 (0)	4 (9)	4 (2)
Intercostal (%)	3 (2)	0 (0)	3 (2)
Pectoralis minor (%)	2 (2)	0 (0)	2 (1)
Trapezius (%)	1 (1)	0 (0)	1 (1)
Fasciocutaneous (%)	0 (0)	1 (2)	1 (1)
Omentum (%)	0 (0)	0 (0)	0 (0)
Deltoid (%)	0 (0)	1 (2)	1 (1)
Total (%)	116 (100)	47 (100)	163 (100)
Average No. of flaps per patient	1.96	1.66	1.71+0.72 (range: 1–4)

with intrathoracic reconstruction (54% versus 16%; $P<0.01$). Fistulas were present in 15% of patients in the following order of decreasing frequency: bronchopleural, bronchopleurocutaneous, bronchogastric, and esophagopleural. Other indications for muscle flap reconstruction included osteoradionecrosis of ribs, desmoid tumor, invasive thymoma, gastric conduit leak, graft failure after lung transplant, sternal and spinal hardware exposures, and pectus carinatum.

The total number of flaps utilized for all reconstructions was 163, with an average of 1.71±0.72 flaps per patient (range, 1–4 flaps). Intrathoracic reconstructions were most likely to require both the LD and serratus anterior (SA) muscle flaps (85%). Chest wall reconstruction utilized a variety of flaps, but the PM and LD muscles remained the workhorse flaps, accounting for 64% of all flaps used. Less common flaps utilized included the external oblique, paraspinal, intercostal muscles, and the omentum (Table 3). A total of 63 patients (69%) required thoracoplasty with an average of 1.6 ribs (range, 0–12) resected. The majority of intrathoracic and chest wall reconstruction patients required rib resection (73% and 58%, respectively).

Table 4. Rib Resection and the Use of Mesh in Thoracic Reconstruction

	Intrathoracic	Chest Wall	Total
Patients requiring rib resection (%)	49 (73)	14 (58)	63 (69)
Average No. of ribs resected	1.5±1.2	2.0±2.4	1.6±1.6
No. of patients requiring mesh	5 (7)	6 (25)	11 (12)*
Gor-Tex (%)	3 (60)	1 (16)	4 (36)
Vicryl (%)	1 (20)	2 (33)	3 (27)
Prolene (%)	1 (20)		1 (9)
Mearlex (%)		1 (16)	1 (9)
Methylmethacrylate (%)		1 (16)	1 (9)
Unspecified (%)		1 (16)	1 (9)
No. of ribs resected	No. of patients (%)	Requiring mesh (%†)	*P*
0	28 (31)	2 (7)	<0.01
1–2	43 (47)	2 (6)	<0.01
3–4	17 (19)	4 (24)	<0.01
5–10	3 (3)	3 (100)	<0.01

*$P < 0.03$.

Of these patients, 11 patients (12%) required mesh reconstruction (Table 4). All patients (100%) with 5 or more ribs resected required mesh, whereas only 24% of those with 3–4 ribs resected required mesh. In patients with 0–2 ribs resected, only 6% required mesh ($P < 0.01$). Chest wall reconstruction patients were more likely to require mesh (25% versus 7%; $P < 0.05$; Table 4). Interestingly, the number of ribs resected and the use of mesh did not impact overall complications ($P = 0.5$). In the chest wall reconstruction group, the number of ribs resected was related to overall LOS ($P < 0.01$).

None of the mesh reconstructions in this series required explantation although mesh removal was necessitated for 1 patient who presented from an outside hospital with infected polytetrafluoroethylene mesh.

The average intubation time for patients undergoing intrathoracic reconstruction (5.51±20.0 days) was significantly higher than for patients undergoing chest wall reconstruction (0.04±0.2 days), $P < 0.05$.

Patients with intrathoracic pathology were more likely to require a longer hospital stay (24±34 days) when compared with patients with chest wall pathology (12±18), $P < 0.05$. Men were more likely to require a longer length of hospital stay (25±36 days) than women (11±16 days), $P < 0.05$, although there

was no difference between sex with respect to diagnosis, comorbidities, or total complications. The total number of complications did not vary between the 2 groups. By univariate analysis, LOS, age, and total complications were unrelated.

The average number of complications did not differ between the 2 groups (chest wall: 0.42 ± 0.97 and intrathoracic: 0.55 ± 1.02; $P = 0.1$). Complications requiring operative or procedural intervention included hematoma, seroma, abscess, wound recurrence, persistent or recurrent fistula, and pneumothorax. Of these, only 6 required reoperation (4.9%). Two hematomas required washout and reclosure. Two persistent bronchopleural fistulas required bronchial gluing, thoracostomy tubes, and 1 late Eloesser flap. One persistent bronchopleural fistula required a return to the OR for successful adjustment of flap inset. Two recurrent chest wall wounds required formal surgical debridement and an additional muscle flap for definitive closure.

In this consecutive series of patients, 2 patients died within 30 days (3%). A total of 29 patients died over the course of follow-up, which was up to 6.8 years (32%; Table 5). One-year estimated survival was 83% for those undergoing chest wall reconstruction, and 59% in those undergoing intrathoracic reconstruction ($P = 0.0048$).

There were no differences in sex for the total number of complications (female: 0.50 ± 0.94 and male: 0.41 ± 0.84; $P = 0.6$). However, 1-year estimated survival was 81.0% for females and 58.0% for males ($P < 0.05$).

The Fisher exact test was used to evaluate the relationship between patient condition and outcome. In the intrathoracic reconstruction group, univariate predictors of complications included total number of comorbidities and LOS ($P < 0.01$). In the chest wall reconstruction group, there was no relationship among the total number of comorbidities, complications, LOS, and age. There was a relationship among the total number of flaps required, the number of ribs resected, and overall LOS ($P<0.01$). There was no relationship between BMI or total complications or LOS in these groups. A prolonged intubation time was associated with an increase LOS ($P<0.0001$) but not to any other factors.

When the effects of these variables were controlled for in a multivariate analysis, the number of comorbidities was found to impact the total number of complications and the number of comorbidities and intubation time resulted in a prolonged LOS ($P<0.05$). However, these factors did not influence overall patient survival. Average series follow-up was 212 days (range, 3 days to 6.8 years; Table 5).

DISCUSSION

General Principles and Indications for Thoracic Reconstruction

In benign disease, empyema is one of the most common indications for intervention, and after pulmonary malignancy, empyema was one of the most common indications for malignancy. Successful management of empyema, and often concomitant bronchopleural fistula, is challenging. Adequate drainage of the fluid collection, direct closure of the bronchopleural fistula after debridement of devitalized tissue, inset of a muscle flap around the fistula closure site, and obliteration of local residual dead space through a combination of thoracoplasty and intrathoracic muscle transposition remain the mainstays of therapy. Both local flaps and free flaps have been well described for use in this setting.[3,17–21]

Perioperative Considerations

A successful outcome for complex patients requiring chest wall reconstruction demands a multidisciplinary approach to care. The patient's general medical condition and nutritional status must be optimized, if possible. Up to 40% of all pneumonectomy patients present with malnutrition.[22–24] Awareness of the patient's pulmonary function is crucial as patients with poor pulmonary function may require prolonged (and even permanent) ventilation. Anatomically, pulmonary resections with bronchial stumps at the main or intermediate bronchus are

Table 5. Patient Outcomes

Patient Course and Outcomes	Intrathoracic	Chest Wall	Total	Range
Mean hospital stay (d)*	24 ± 34	12 ± 18	20 ± 31	1 to 159
Mean follow-up (d)	228 ± 971	203 ± 936	212 ± 955	3 days to 6.8 years
Avg. No. of complications	0.55 ± 1.02	0.42 ± 0.97	0.44 ± 0.87	0 to 5
Intubation time (d)*	5.51 ± 20.00	0.04 ± 0.21	4.07 ± 16.46	1 to 110
1 year survival,† %	83	59		
30-day mortality (%)	2 (3)	0 (0)		
Total mortality (%)	24 (36)	5 (21)	29 (32)	

*$P < 0.05$.
†$P < 0.0048$.

more likely to result in bronchopleural fistula than bronchial stumps at the lobar bronchus.[25]

Evolution of Technique

Intrathoracic reconstruction in the setting of malignancy requires a detailed dictated description of the operative reconstruction. Postoperative follow-up to evaluate for malignancy can be challenging after muscle flap transposition. An accurate understanding of the patient's "new normal" is crucial. Intercostal muscle flaps can be useful to reinforce suture lines, particularly in the setting of a previously radiated bronchus.[26] The LD and SA muscle flaps are the workhorse flaps for intrathoracic defects. In the setting of a previous non-muscle sparing thoracotomy, only the most proximal aspect of the latissimus muscle may be viable.[27] For lower intrathoracic defects, the LD muscle based on the lumbar perforators provides excellent coverage. A small counter incision to detach its humeral incision limits the morbidity of the reconstruction. The SA muscle's attachment to the scapula is maintained by suturing the serratus muscle margins to the site of intrathoracic muscle transposition. This minimizes scapular winging and facilitates shoulder rotation. Placement of drains both in the intrathoracic and extrathoracic space is crucial. The 2 spaces ultimately become sealed to the point that these separate drains do not communicate with each other.

Intrathoracic reconstruction is typically required for infectious complications in the setting of previous malignancy. The development of video-assisted thoracic surgery (VATS) in the early 1990s has led to a dramatic transition in the management of intrathoracic pathologies, particularly malignancy.[28] A VATS approach has been demonstrated to reduce postoperative pain, shoulder dysfunction, and limit early pulmonary impairment.[29] In the setting of these minimally invasive interventions, complications such as bronchopleural fistula and empyema can still develop. Several patients have been successfully treated in conjunction with the thoracic surgery service using VATS debridement and thoracomyoplasty. A limited incision is used, which avoids a full thoracotomy and rib spreading. This minimally invasive approach to intrathoracic reconstruction will likely improve patient morbidity, limit complications, and decrease pain.

Reconstruction for Chest Wall Stability

In this series, less than 10% of all patients required chest wall stabilization as an adjunct to soft-tissue reconstruction. The majority of patients who required mesh presented in the setting of malignancy or recurrence of malignancy. There was only 1 patient who required mesh in the setting of infection. When more than 5 ribs were resected, mesh was used in all cases (100%). Only 6% of all patients with 0–2 ribs resected required mesh reconstruction; mesh was used only in 24% of the times when 3–4 ribs were resected. In these patients, the use of mesh was dependent in part on the location of the defect. Anterior defects were more likely to require mesh, whereas posterior defects stabilized by the scapula did not require formal or definitive chest wall stabilization. An increasing number of rib resections in chest wall defects resulted in longer hospital stays but without a difference in overall complications. Rib resection in intrathoracic reconstruction was unrelated to the number of complications or LOS.

Le Roux and Shama[30] defined the ideal prosthetic material as one that is rigid to moderate paradoxical chest motion, inert to allow for tissue ingrowth, malleable to achieve appropriate contour, and radiolucent to allow for underlying radiographic follow-up. Numerous autogenous and alloplastic materials have been described although no ideal material has yet emerged. Deschamps et al[16] demonstrated no difference in outcome or complication rate when comparing the use of Prolene mesh and polytetrafluoroethylene. However, recent reports support the use of newer prosthetic materials such as acellular collagen matrices over conventional materials in complex reoperative cases.[31] In this series, the use of mesh was minimized. Mesh was always utilized if 5 or more ribs were resected, or if chest wall instability was noted. For example, although a 4-rib resection in the posterior thorax stabilized by the scapula may not need mesh, a defect in the anterior thorax is more likely to need mesh. Late muscle fibrosis that develops postoperatively can be sufficient to allow for stable ventilation.

Long-term Outcomes

Patients who require chest wall reconstruction are frequently medically complex. Long-term survival is strongly related to the overall stage and prognosis of their initial pathologic diagnosis. Nevertheless, chest wall reconstruction is a safe and successful intervention that reliably treats complex and challenging problems. The typical patient who requires chest wall reconstruction is in their mid 50s and carries a diagnosis of malignancy. Many of these patients will require rib resection, and more aggressive rib resections can lead to an increased hospital stay. Reconstruction for these patients will likely utilize the PM and LD muscle flaps and will lead to a hospital stay of approximately 12 days.

The typical patient who requires intrathoracic reconstruction will be a male in his 60s, who is most

likely presenting with an infectious problem although this often occurs in the context of a previously treated malignancy. The majority of these patients will require rib resection for flap access and reconstruction utilizing LD and SA muscle flaps. This patient population will require the longest hospital stay, on average 23 days, and will have the poorest 1-year survival (59% $P = 0.0048$).

CONCLUSIONS

A retrospective review of 91 consecutive patients who underwent chest wall reconstruction between 2001 and 2013 was performed. Success is dependent on a multidisciplinary approach toward care, patient optimization, and thoughtful but aggressive use of muscle flaps as part of the reconstructive plan.

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