Intrathoracic Muscle Flaps

An Account of Their Use in the Management of 100 Consecutive Patients

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One hundred consecutive patients underwent intrathoracic muscle transposition between May 1977 and February 1988. Seventy-three procedures were performed to manage the complications of infection, which included treatment of bronchopleural fistula, postpneumonectomy empyema, perforations of the heart or great vessels, and fistulae of the esophagus and trachea. Prophylactic reinforcement of the repaired viscus was done in the remaining 27 patients because of either increased airway tension or previous intrathoracic radiation. There were 71 male and 29 female patients. Ages ranged from 16 to 82 years (median, 58 years). One hundred thirty muscle transpositions were performed and included 60 serratus anterior flaps, 33 latissimus dorsi, 28 pectoralis major, 3 intercostal, 2 rectus abdominus, and 4 others. The number of operations per patient ranged from 1 to 13 (median, 2). Seventy-six complications occurred in 35 patients. There were 16 operative deaths. Follow-up ranged from 3.4 to 150.7 months (median, 41 months). Infection was controlled or avoided in 73 patients. Forty-three of the operative survivors died. Cause of death was cancer in 27 patients, cardiac in 4, pulmonary in 3, infection in 3, suicide in 1, and unknown in 5. We conclude that although associated with a significant morbidity and mortality, intrathoracic muscle transposition when there is an actual or potential leak of an intrathoracic viscus can be life saving. Long-term survival, however, is determined by the pre-existing thoracic disorder.

INTRATHORACIC MUSCLE TRANSPOSITION is not new.[1-5] In 1911 Abrashanoff[1] reported the use of muscle to close bronchopleural fistulae. Five years later, Robinson reported open pleural drainage combined with transposition of the latissimus dorsi muscle to successfully obliterate a chronic nontuberculous empyema cavity.[2] It was not until 1938, however, that Gray reported the use of a smaller thoracotomy window through which muscle flaps could be passed when transposing them into the chest.[6] Since then other small refinements in intrathoracic muscle transposition have been made, but all are based on the concept of transposing autogenous tissue into the chest.[7-14]

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The authors have been performing intrathoracic muscle transposition for the past 12 years.[15-21] The majority of our experience, however, has been accumulated since 1985. In 1988 we presented a preliminary report of a smaller number of patients with a shorter follow-up period.[20] Since then we have expanded that number with a more significant follow-up in an effort to delineate the true outcome of these attempts at improving life-threatening situations. We have also attempted to define criteria for those patients who would benefit from leaving the pleural cavity open at the time of muscle transposition.

Materials and Methods

Clinical Data

One hundred consecutive patients who underwent intrathoracic muscle flaps between May 1977 and February 1988 were reviewed. Seventy-three patients had an intrathoracic infection at the time of muscle transposition. Forty-seven patients had bronchopleural fistulae (23 with postpneumonectomy empyema), 11 had perforations of the heart or great vessels, 8 had esophageal fistula, 5 had postpneumonectomy empyema alone, and 2 had empyema. Sixteen of these patients had previous radiation. The remaining 27 patients had a potential wound-healing problem secondary to either tension on the airway (18 patients) or to previous intrathoracic radiation (9 patients).

There were 71 male and 29 female patients. Ages ranged from 16 to 82 years, with a median of 58 years. These 100 patients had 130 intrathoracic muscle transpositions performed, which included the serratus anterior in 60 patients, latissimus dorsi in 33, pectoralis major in 28, intercostal in 3, rectus abdominus in 2, and other in 4. Muscle transpositions were done on the right in 60 patients, the left in 38, and bilaterally in 2. Four patients had the omentum transposed to the intrathoracic position, all as a salvage procedure when a previous muscle flap did not perform the original task. Three of these omental transpositions were for perforation of the heart or great vessels and one was for recurrent bronchopleural fistula after potential intrathoracic muscle necrosis.

Operative Procedure

The thorax was entered either through a standard posterolateral thoracotomy after sparing both the latissimus dorsi and serratus anterior muscles or through a median sternotomy. The intrathoracic disorder was repaired before consideration of muscle transposition. Thus any fistula of the esophagus or airway or perforation of the heart or great vessels was closed first. After this muscle was transposed to reinforce these direct closures. In three patients the airway could not be closed directly. In these latter situations muscle was inserted into the open fistula and sutured to its edge. In some patients muscle was also used to obliterate small residual pleural spaces but no effort was made to completely obliterate large cavities (postpneumonectomy space). The mobilization and intrathoracic transposition of various muscles have been previously described.[15-23]

A specific muscle was then chosen considering such factors as the location of the intrathoracic defect, the axis and arc of the selected muscle, potential loss of function and external deformity that could result from use of the selected muscle, and whether the latissimus dorsi muscle had been divided during a previous thoracotomy. The muscle was generally elevated on its proximal dominant blood supply. A 7- to 10-cm segment of rib (usually the second or third) was resected near the axis of the muscle, which was in the posterior axillary line for the latissimus dorsi, the mid axillary line for the serratus anterior, and at the mid clavicular level for the pectoralis major. The rectus abdominus muscle and omentum entered the chest through either a subcutaneous tunnel or *via* the diaphragm. The muscle was then sutured directly to the repaired intrathoracic structure.

If obvious infection was associated with a large residual pleural cavity (postpneumonectomy empyema), the entire thorax was left opened and wet dressings of Betadine (Purdue Frederick Co., Norwalk, CT) solution diluted 20:1 were placed in the thorax and changed every 48 hours in the operating room until the muscle flap was adherent to surrounding structures. If necessary further debridement was also accomplished before redressing the wound. Dressing changes were then accomplished three to four times per day in the patient's room.

Pleural tissue cultures were not used to determine timing of chest wall closure. Instead, when healthy granulation tissue with no evidence of gross exudate was present throughout the pleural space, the chest was then closed by obliterating the pleural cavity with an antibiotic solution consisting of 0.5 g neomycin, 0.1 g polymyxin B sulfate, and 80 mg gentamicin per liter of saline, and the chest wound closed by separation of the soft-tissue planes, mobilization of the adjacent muscles, and water-tight approximation of the different chest wall layers (Clagett procedure). If the residual pleural cavity was small enough to allow complete obliteration with a transposed muscle, then the Clagett procedure was not necessary. Otherwise no effort was made to completely fill the pleural cavity with autogenous tissue. These procedures and their rationale have been discussed before.[15-23]

The thoracotomy was initially closed in 55 patients. Thirty-four of the 45 patients in whom the thoracotomy was left open were eventually closed. Reasons for not closing the chest wall in the remaining 11 patients included sepsis in 5, recurrent cancer in 4, and patient refusal in 2.

Results

Thirty-five of the 100 patients had 76 early complications (Table 1). Sixty-one complications occurred in 28 patients in the infected group and 15 complications occurred in 7 patients in the prophylactic group. There were 16 operative deaths; 10 occurred within the first 30 days after operation and 6 occurred between 35 and 212 days but during the initial hospitalization. Twelve deaths occurred in the 73 patients with infection (16.4%). Cause of death in these 12 patients included sepsis in 6 patients,

TABLE 1. *Early Complications in 100 Consecutive Patients Undergoing Intrathoracic Muscle Transposition*

Complications	No. of Patients
Infected group (73 patients)	
Respiratory failure	16
Wound infection	14
Tracheostomy	12
Postpneumonectomy empyema	4
Bronchopleural fistula	4
Flap necrosis	4
Sepsis	3
Myocardial infarction	2
Hemorrhage	2
Prophylactic group (23 patients)	
Respiratory failure	8
Tracheostomy	3
Postpneumonectomy empyema	1
Bronchopleural fistula	1
Wound infection	1
Sepsis	1
Total	76

hemorrhage from the heart or great vessels in 2, adult respiratory distress syndrome in 2, and myocardial infarction in 2. Four deaths occurred in the 27 patients (14.8%) undergoing prophylactic muscle transposition (3 from adult respiratory distress syndrome and 1 from sepsis).

The number of operations per patient ranged from 1 to 13, with a median of 2 operations. Forty-five patients, however, had only one operation. Multiple operations were frequently wound debridements. The number of days in the hospital ranged from 1 to 212, with a median of 26 days. If operative deaths were excluded, the number of days in the hospital ranged from 5 to 137, with a median of 25 days. The number of days in the hospital after the chest wall was closed for operative survivors ranged from 4 to 135, with a median of 14 days.

Follow-up of the 84 operative survivors ranged from 3.4 to 150.7 months, with a median of 41 months. At the time of this report, 43 operative survivors have died. Cause of death was cancer in 27 patients, cardiac failure in 4, pulmonary failure in 3, persistent or recurrent infection in 3, suicide in 1, and unknown in 5. Forty-one patients are alive. Follow-up in these 41 patients has ranged from 23.2 months to 150.7 months, with a median of 60.9 months. Thirty-nine patients have no signs or symptoms of infection, one with postpneumonectomy empyema has a draining chest wall sinus tract, and one with postpneumonectomy empyema has an open pleural window.

At last follow-up or at the time of death, infection was either controlled or avoided, with the initial management in 69 patients. An additional four patients (three with postpneumonectomy empyema and one with bronchopleural fistula) were salvaged with another intrathoracic muscle flap, bringing the overall total number of patients successfully treated to 73 (Table 2). Eventually 51 of the 73 patients in the infected group (69.9%) and 22 of the 27 patients in the prophylactic group (81.5%) were successfully treated. Also successfully treated were 33 of the 47 patients (70.2%) who presented with bronchopleural fistula and 18 of 28 (64.3%) who presented with postpneumonectomy empyema. The remaining 27 patients were all considered failures, eight of whom had their pleural cavity open at the time of death. Cause of failure were operative deaths in 16 patients and infection in 11.

Late complications included shoulder discomfort in seven patients, three of whom developed significant scapular winging. One of the latter patients underwent subtotal scapular resection without relief of symptoms. Postpneumonectomy empyema developed in six patients, three of whom were salvaged with additional open drainage and muscle transposition. Recurrent bronchopleural fistula and esophageal fistula developed in one patient each, one of whom (bronchopleural fistula) was salvaged with another muscle flap. Three patients developed late tracheal stenosis. Each of these latter patients had a tracheal tumor that had been previously irradiated. After resection tracheal dehiscense occurred, which led to stenosis in all three patients and fistula in two. All three patients eventually died.

TABLE 2. *Overall Results According to Indication for Intrathoracic Muscle Transposition*

Indication	No. of Patients	Result: Excellent	Result: Failure
Infected group (73 patients)			
Bronchopleural fistula and postpneumonectomy empyema	23	15	8
Bronchopleural fistula	24		
Heart or great vessel perforation	11	18	6
Esophageal fistula	8	7	4
Postpneumonectomy		7	1
empyema	5	3	2
Empyema	2	1	1
Prophylactic group (27 patients)			
Airway tension	18	13	5
Intrathoracic radiation	9	9	0
Total	100	73	27

Discussion

These 100 patients represent a collection of desperately ill patients whose clinical conditions have been a therapeutic challenge over the years. In 1916 Robinson wrote that 'certain thoracic diseases which for generations have fallen to the lot of the surgeon are yet badly handled. Conspicuous among these is that patriarch of the surgical scrap heap, chronic empyema. There is obvious opportunity for improvement in the treatment....'[2] Certainly most of the problems encountered in this group of patients qualify for the 'surgical scrap heap.' As was true in Robinson's day, we continue to seek a more reliable method of managing them.

Long-term successful management of all these conditions, most of which have associated empyema, has three components: pleural drainage, closure of any associated fistula, and obliteration of the residual pleural cavity at the time of chest wall closure. Pleural drainage to manage empyema and control infection must be done first. If a fistula is present, the fistula must be closed and reinforced with muscle before obliteration of the pleural cavity and closure of the chest wall. The techniques to accomplish these three phases have evolved with time and continue to undergo modification.

Early in our experience we obtained pleural drainage by chest tube thoracostomy. After salvaging patients who failed intrathoracic muscle transposition with a subsequent muscle flap and open pleural drainage, we gradually evolved to open pleural drainage as our preferred initial drainage procedure. It is of utmost importance to realize that open pleural drainage, muscle transposition, and obliteration of the residual pleural cavity must be done in a step-wise sequence with no 'short cuts.' Progression from step-to-step is determined by the condition of the wound.

Step 1. Open drainage of the empyema with closure of the fistula.

Step 2. Intrathoracic muscle transposition.

Step 3. Repeated pleural dressing changes and mechanical irrigation with observation to insure that the muscle has become adherent to adjacent structures and that the cavity is clean.

Step 4. Obliteration of the pleural cavity by installation of antibiotic fluid and secondary closure of the chest wall.

Failure in our experience results from one or more of the following: recurrence of the fistula, closure of a grossly contaminated pleural space, or loss of antibiotic fluid through a poorly sealed chest wall.

Clearly intrathoracic muscle transposition is the pivotal point that determines success. In the past recurrence of these conditions frequently followed dehiscense of the repaired viscus. Well-vascularized striated skeletal muscle prevents dehiscense and is an excellent tissue to transpose into the thorax. The experience in recent years has amply demonstrated that muscle behaves very favorably when placed in contaminated wounds.[15-21,24] Not only will muscle seal a repaired hollow viscus, but muscle will also obliterate small residual pleural space and may potentially increase antibiotic levels to an isolated pleural cavity.[13]

The usual method of open pleural drainage is limited resection of one or two ribs in the most dependent portion of the pleural cavity with suturing of the skin edges to the underlying pleura. This procedure was described by Robinson in 1916[2] and later by Eloesser in 1935[25] and has evolved into our current practice of leaving open the entire thoracotomy, which, in our opinion, allows for more thorough debridement of all recesses of the pleural space and detection of occult fistulae.

Leaving the thoracotomy open is generally well tolerated, even in the critically ill patient, and discomfort is often no more than that experienced with the smaller open pleural window. Usually the patient can breathe spontaneously, and early extubation is often possible if there is no persistent bronchopleural fistula. Mediastinal flutter has not been observed in our patients, probably because the pleural cavity is packed with gauze, which tends to stabilize the mediastinum. Dressing changes usually can be accomplished without intravenous sedation after the first few days.

Confusion exists about whether the chest should be closed primarily or left open. When muscle transposition is used prophylactically to reinforce a tracheal or bronchial anastomosis in a noncontaminated thorax; we close the thoracotomy at the time of muscle transposition. If, however, an empyema is present in association with a fistula of the esophagus or airway or with a perforation of the heart and great vessels, we prefer to leave the thoracotomy open for dressing changes after muscle transposition. This is especially true if there is an associated postpneumonectomy empyema. Smaller empyemas with entrapped lung, however, may be successfully treated by decorticated and muscle transposition without open drainage. But if decortication does not allow full expansion of the lung and complete obliteration of the cavity, we tend to leave the thorax open. In this last situation prolonged mechanical ventilation is often necessary.

Meticulous attention to the condition of the pleura at the time of dressing change is critical to successful outcome. Frequent debridement is mandatory. The muscle must eventually adhere to the viscus to prevent recurrence of the fistula. Gentle pressure of the packing against the muscle flap, combined with limited dressing changes in the operating room during the first few days after transposition, will prevent collection of hematoma and exudate between the muscle and repaired viscus to ensure adherence. When the transposed muscle becomes adherent to the mediastinum, the pack is changed in the patient's room three to four times daily, more frequently if drainage is excessive. Additional cleansing at these dressing changes is also obtained with a pulsatile hand-held shower head or water pik.

The serratus anterior, latissimus dorsi, and pectoralis major muscles are used in the majority of intrathoracic transpositions. All three muscles have a large, dominant blood supply that is the axis of the muscle flap. The muscles are generally transposed by dividing all of their chest wall attachments. The latissimus dorsi and the pectoralis major muscles result in little cosmetic or functional defect. Transposition of the serratus anterior muscle, however, results in some degree of scapular winging. To minimize this latter complication, the serratus anterior muscle is carefully dissected to preserve intact the top two to three slips of muscle whenever possible. Three of our patients had marked winging of the scapula, which was very aggravating. One of these patients had subtotal scapular resection but discomfort and dissatisfaction with winging still persisted. Nonetheless we believe that in the majority of patients the scapular winging is a reasonable trade off for the gain that can be achieved in control of thoracic infection. One additional consideration regarding the serratus anterior muscle is that a previous standard posterolateral thoracotomy rarely divides more than just the lower one fifth of the muscle, leaving the majority of the muscle intact for subsequent transposition. The serratus anterior muscle is our muscle flap of choice for most of these conditions and was used in nearly one half of our patients.

The authors emphasize that muscles, in general, are transposed into the chest to reinforce closure of leaks and that the primary goal of the muscle is to prevent recurrence of the fistula and not to obliterate pleural dead space. It is our opinion that large pleural spaces after pneumonectomy cannot be completely obliterated with autogenous tissue, as suggested by Miller et al.,[15] and we do not recommend this approach. Nor do we use thoracoplasty for the same reason. Instead we believe this problem is best handled by secondary closure of the chest wall after first filling the pleural cavity with an antibiotic solution as described originally by Clagett and Geraci in 1963,[26] and modified by us.[17,19-21] However if a residual pleural space is small (less than 300 cc), a secondary benefit of the muscle is obliteration of this space.

We believe that when confronted with a life-threatening intrathoracic infection, muscle flaps present an excellent opportunity to salvage a number of otherwise hopeless patients. When basic general surgical and wound healing principles are followed, intrathoracic muscle transposition can control these potentially tragic situations in approximately 75% of the patients. We urge their consideration.

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References

1. Abrashanoff. Plastische Methode der Schliessung von Fistelgangen, welche von inneren Organen kommen. Zentralbl Chir 1911; 38: 186.
2. Robinson S. The treatment of chronic nontuberculous empyema. Surg Gynecol Obstet 1916; 22:557–571.
3. Eggers C. The treatment of bronchial fistulae. Ann Surg 1920; 72: 345–351.
4. Pool EH, Garlock JH. A treatment of persistent bronchial fistula: An experimental and clinical study. Ann Surg 1929; 90:213–237.
5. Wangensteen OH. The pedicle muscle flap in the closure of persistent bronchopleural fistula: with description of preservation and employment of the intercostal muscle bundles by a process of ribboning (for the avoidance of abdominal hernia) in the obliteration of large chronic empyema cavities. J Thorac Surg 1935; 5:27–53.
6. Gray HK. The use of pedicle muscle grafts in facilitating obliteration of large, chronic, nontuberculous, pleural empyema cavities. Minn Med 1938; 21:608–610.
7. Maier HC, Luomanen RKJ. Pectoral myoplasty for closure of residual empyema cavity and bronchial fistula. Surgery 1949; 25: 621–624.
8. Tessier P, Hertzog P, Toty L. Le Poumon et le Cceur. Les Myoplasties de Comblement des Pleurectomies, Sept. 1956, Paris.
9. Barker WL, Faber LP, Ostermiller WE Jr, et al. Management of persistent bronchopleural fistulas. J Thorac Cardiovasc Surg 1971; 62:393–401.
10. Demos NJ, Timmes JJ. Myoplasty for closure of tracheobronchial fistula. Ann Thorac Surg 1973; 15:88–93.
11. Hugill JV, Curtin JW. Successful treatment for exposure of a Dacron aorta, with surrounding infection: case report. Plast Reconstr Surg 1978; 62:455–457.
12. Hankins JR, Miller JE, McLaughlin JS. The use of chest wall muscle flaps to close bronchopleural fistulas: experience with 21 patients. Ann Thorac Surg 1978; 25:491–499.
13. Miller JI, Mansour KA, Nahai F, et al. Single stage complete muscle flap, closure of postpneumonectomy empyema space: a new method and possible solution to a disturbing complication. Ann Thorac Surg 1984; 38:227–231.
14. Feller AM, Russell RC, Roth AC, et al. Antibacterial drug delivery into fibrotic cavities using muscle flaps. Eur J Plast Surg (In press).
15. Pairolero PC, Arnold PG. Bronchopleural fistula: treatment by transposition of pectoralis major muscle. J Thorac Cardiovasc Surg 1980; 79:142–145.
16. Schaff HV, Arnold PG, Reeder GS. Late mediastinal infection and pseudoaneurysm following left ventricular aneurysmectomy: repair utilizing a pectoralis major muscle flap. J Thorac Cardiovasc Surg 1982; 84:912–916.
17. Pairolero PC, Arnold PG, Piehler JM. Intrathoracic transposition of extrathoracic skeletal muscle. J Thorac Cardiovasc Surg 1983; 86:809–817.
18. Arnold PG, Pairolero PC, Waldorf JC. The serratus anterior muscle: Intrathoracic and extrathoracic utilization. Plast Reconstr Surg 1984; 73:240–246.
19. Arnold PG, Pairolero PC. Intrathoracic muscle flaps in surgical management of life-threatening hemorrhage from the heart and great vessels. Plast Reconstr Surg 1989; 84:92–97.
20. Arnold PG, Pairolero PC. Intrathoracic muscle flaps: A 10 year experience in the management of life-threatening infections. Plast Reconstr Surg 1989; 84:92–98.
21. Pairolero PC, Arnold PG, Trastek VF, et al. Postpneumonectomy empyema: the roll of intrathoracic muscle transposition. J Thorac Cardiovasc Surg (In press).
22. McCraw JB, Arnold PG. McCraw and Arnold's Atlas of Muscle and Musculocutaneous Flaps. Norfolk, VA: Hampton Press, 1986.
23. Arnold PG, Mathes S, McCraw JB, et al. Muscle and Musculocutaneous Flaps: The Videotape. Norfolk, VA: Hampton Press, 1987.
24. Chang N, Mathes SJ. Comparison of the effect of bacterial innoculation in musculocutaneous and random-pattern flaps. Plast Reconstr Surg 1982; 70:1–10.
25. Eloesser L. An operation for tuberculous empyema. Surg Gynecol Obstet 1935; 60:1096–1097.
26. Clagett OT, Geraci JE. A procedure for the management of postpneumonectomy empyema. J Thorac Cardiovasc Surg 1963; 45: 141–145.

Discussion

Dr. E. Stanley Crawford (Houston, Texas): We congratulate the authors for their report of an extensive experience using mobilized viable muscle in the treatment of complications after lung and thoracic vascular operations, including bronchopleural fistula, empyema, and ruptured false aneurysm of the heart and great vessels. We have followed their work and have used these principles in the treatment of 38 patients with graft infections of the ascending aorta and ascending aorta and transverse aortic arch and in three patients with aortoesophageal fistulae. Viable tissue coverage of grafts using mobilized local structures in 18, omentum in 9, muscle in 9, and musculocuntaneous flaps in 2 were used in the former and mobilized omentum was used to close the esophagus and to wrap the graft in the latter. Initial high-dose intravenous antibiotics followed by lifetime oral suppression antibiotic therapy was used in all patients. Eighty per cent of the former and all of the latter patients were early survivors. Follow-up ranging from 3 months to 6.5 years indicated that 75% were alive and without signs of infection complications. All