Second surgery for complications of major pulmonary resection—the technique of thoracoplasty with muscle flap

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Abstract: Second surgery for postoperative complications after lung resection is one of the important issues that thoracic surgeons must overcome. Chronic empyema after lung resection, which is caused by bronchopleural or pleural fistula remains a challenge in modern medicine. Especially in cases in which decortication is not indicated, treatment is difficult, hospitalization is prolonged, and the condition is sometimes life-threatening. Surgical treatment of chronic empyema requires not only decortication and debridement, but also closure of the bronchopleural fistula and obliteration of dead space. From this viewpoint, thoracoplasty and muscle flap transposition are important techniques that lead to complete and reliable closure of the empyema cavity. Although they are performed less frequently today, they are procedures with which every thoracic surgeon should be familiar. This clinical practice review focuses on the use of muscle flaps in thoracoplasty and describes the historical background, types of muscle flaps, tips on surgical techniques, and treatment results. There is a wide variety of types and utilization of muscle flaps. Since the selection of an appropriate muscle flap is directly related to the success of the treatment, careful preoperative planning is necessary. It is important to understand the characteristics of each type of muscle flap and to select the appropriate technique for the patient's pathological and general condition.

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Introduction

Background

Second surgery for postoperative complications after lung resection is one of the important issues that thoracic surgeons must overcome. Especially, chronic empyema associated with intrathoracic infection is the most serious and difficult-to-treat complication following lung resection, and thoracic surgeons must be familiar with how to manage it. Chronic empyema associated with persistent pulmonary or bronchopleural fistulas after pneumonectomy or lung resection is refractory, and often cannot be ameliorated with drainage and antimicrobial therapy alone.

Rationale and knowledge gap

Surgical treatment of chronic empyema requires not only decortication and debridement, but also closure of the bronchopleural fistula and obliteration of dead space (1). The combination of thoracoplasty and intrathoracic muscle transposition is useful as a radical cure for chronic empyema. Although they are performed less frequently today, they are procedures with which every thoracic surgeon should be familiar.

Objective

It is important to understand the characteristics of each type of muscle flap and to select the appropriate technique for the patient's pathological and general condition. This review focuses on the use of muscle flaps in thoracoplasty and describes the historical background, types of muscle flaps, tips on surgical techniques, and treatment results.

Historical background

Thoracoplasty was introduced at the end of the 19th century as a technique to obliterate empyema by collapsing the chest wall (2) and was initially developed as a technique to cure tuberculosis by collapsing the lungs. The technique contributed greatly to the development of general thoracic surgery as we know it today (3), but its popularity declined after World War II, with the spread of anti-tuberculosis drugs (4). The main role of thoracoplasty today is to cure chronic empyema, and the technique proposed by Andrews and colleagues (5,6) was the foundation for its widespread use. Muscle transposition was performed in the early 20th century by surgeons such as Abrashanoff (7), Eggers (8), and Archibald (9). In the 1980s and 1990s, when thoracic surgeons and plastic surgeons at the Mayo Clinic demonstrated its usefulness in the treatment of severe thoracic infections, transposition became widely popular (4,10,11).

Preoperative preparation

Since the selection of an appropriate muscle flap is directly related to the success of the treatment, careful preoperative planning is necessary. The main points of evaluation are: (I) evaluation of the location and size of the empyema cavity using computed tomography (CT) or three-dimensional (3D) CT; (II) detailed information regarding the previous surgical technique (especially with regard to open wounds and transected muscle); (III) presence of bronchopleural fistula; and (IV) complications associated with the use of a muscle flap and the difficulty in harvesting it (12,13).

Most patients who are candidates for thoracoplasty or muscle transposition are in poor general health. In particular, in patients with poor nutritional status due to chronic inflammation, often only thin muscle flaps can be created, and preoperative nutritional management is important. Naturally, control of intrathoracic infection is also essential, and appropriate use of antimicrobial agents and drainage through a tube or open-window thoracostomy are required to drain the thoracic cavity before thoracoplasty is performed (13).

Features of the muscle flap and details of the procedure

The muscle flap can be mobilized only by thoracic manipulation and is more versatile, but its ability to attach to infected lesions is weaker. Therefore, a good indication for thoracoplasty using muscle flaps is when intra-thoracic infection is under control to some degree. Various types of muscle flaps are available, and the advantages, disadvantages, and anatomic characteristics of each should be understood (14,15).

The main rules in mobilizing muscle flaps are as follows:

- ❖ Careful attention should be paid to avoid damaging the major nutrient vessels of the muscle. Ischemia or necrosis of muscle flaps can lead to failure (13).
- ❖ When guiding the pedicle muscle flap into the thoracic cavity, select the guiding intercostal space for the shortest route, and beware of twisting or stenosis of the vessels that may obstruct blood flow to the muscle flap. To this end, be aware of the nutrient vessels and innervating nerves, as well as the origin and insertion of the muscles.
- ❖ If a bronchopleural fistula is present, consider suture closure utilizing the edge of a muscle flap or another muscle flap (12).
- ❖ If closure of the thoracic cavity with a single muscle is inadequate, consider using multiple muscle flaps (12,16).
- ❖ The choice of pedicle flap or free flap is based on the type and length of muscle, the site and size of the thoracic cavity, and patient factors, such as muscle volume or damages due to initial surgery (17).

Table 1 shows the summary of feeding vessels and postoperative complications of muscle flaps.

Latissimus dorsi muscle

The latissimus dorsi muscle flap is the most versatile muscle flap used in thoracic and plastic surgery. In thoracic surgery, it is used as filling tissue during thoracoplasty, as well as for covering bronchial transection fistulas and for reconstruction during chest wall resection (18). The latissimus dorsi muscle flap is hemodynamically stable and is versatile in either a stapedial or free muscle valve form (19). The large muscle body allows for the creation of large muscle flaps that extend close to the iliac crest and reach almost all areas of the thorax (18,19). Another advantage

Table 1 Summary of feeding vessels and postoperative complications of muscle flaps

Type of muscle flap	Nutrient vessels	Postoperative complications
Latissimus dorsi muscle	Thoracodorsal blood vessels	Hematomas
		Arm adduction problems
		Arm weakness
Pectoralis major muscle	Thoracoacromial trunk of the subclavian artery	Infection of the fatty tissue
	Perforating branches of the internal mammary artery	
Serratus anterior muscle	Branch from the dorsal thoracic vessels	Winged scapula
	Lateral thoracic vessels	
Rectus abdominis muscle	Superior epigastric vessels	Incisional hernia

of this technique is that it is less likely to cause dysfunction associated with muscle flap harvesting. When a large muscle flap is harvested, especially in women, scarring can cause arm adduction problems and arm weakness, but these problems have been reported to resolve almost completely within one year after surgery (20,21). As described above, the latissimus dorsi muscle flap is very useful, but it should be noted that it cannot be used if a posterolateral incision is made during the initial surgery and the latissimus dorsi muscle is dissected (12,14,16,22-25).

The latissimus dorsi muscle flap can be harvested easily with the patient in the supine position with the affected side up; the muscle flap can be lengthened by dissecting the muscle from the humeral insertion or by separating the pedicle from the fascia (19). The thoracodorsal blood vessels, the main nutrient vessels of the latissimus dorsi muscle, have a long stalk and a large diameter, which stabilizes blood flow. However, because of the thickness of the muscle flap, if the guiding space into the thoracic cavity is not large enough, pressure can cause congestion of blood flow (13). Therefore, if the space between the guiding ribs of the muscle flap is narrow, a partial rib resection is necessary (13,19). The most important aspect of postoperative management is hematoma formation. It has been reported that hematomas form in 79% of cases in which a latissimus dorsi muscle flap is created (26), and it is important to continue drainage until the volume collected is less than 25 cc per day (19). Because of the previously mentioned characteristics, the combination of the latissimus dorsi muscle flap and thoracoplasty is safe and effective, even in severe cases, such as patients with bronchopleural fistula and chronic empyema following pneumonectomy (27,28).

Pectoralis major muscle

The pectoralis major muscle can be harvested even after posterolateral incisional surgery and is an ideal muscle flap, especially for filling the anterior thoracic cavity (12). The pectoralis major muscle has two blood supplies: the thoracoacromial trunk of the subclavian artery and the 2nd through 6th perforating branches of the internal mammary artery (19). The thoracoacromial vessels provide a muscle flap with good mobility and allow for filling of the apex of the thoracic cavity. Perforating branches from the internal mammary and anterior intercostal vessels can be used to create a muscle flap suitable for filling the less mobile superior mediastinal region (24,29).

Nomori *et al.* performed thoracoplasty using a pectoralis major and pectoralis minor muscle flap in five patients with empyema who underwent pneumonectomy through a posterolateral incision and reported successful resolution of empyema in all patients (24). In contrast, it has been suggested that pectoralis major muscle filling for post-pneumonectomy empyema with bronchopleural fistula should be avoided, because it can lead to recurrent empyema due to infection of the muscle flap and fatty tissue (30,31).

Serratus anterior muscle

The main blood supply of the serratus anterior is a branch from the dorsal thoracic vessels, and the lateral thoracic vessels are a secondary source to nourish localized areas (13). Full mobilization of the serratus anterior muscle produces a muscle flap with a volume comparable to that of the latissimus dorsi muscle and can reach any location in the upper half of the thorax, including the hilar region (22,32).

A complication to be aware of when harvesting the serratus anterior muscle flap is winged scapula. The muscles responsible for scapular motion, such as the serratus anterior, fail to hold the scapula close against the back of the rib cage (22,33). This complication is very uncomfortable for the patient, difficult to treat, and sometimes results in poor functional outcomes (33). Strategies to prevent this complication include preservation of the trapezius and rhomboid muscles and fixation of the scapular tip to the chest wall using sutures (34).

Botianu *et al.* (34) reported on 65 cases of suppurative disease in which intra-thoracic transposition was performed using the serratus anterior muscle; of the 65 cases, 12 had post-pneumonectomy empyema and 26 had bronchopleural fistula. Almost all were mobilized using both lateral thoracic vessels and branches of the dorsal thoracic artery, and 75% were combined with other muscle flaps. In addition, intercostal muscle flaps were used for closure of bronchopleural fistulas in all cases, rather than the serratus anterior muscle. The outcome was relatively good, with a postoperative mortality rate of 3%, a rate of recurrence of intra-thoracic infection requiring surgery of 3%, and no cases of winged scapula as a postoperative complication. Although the serratus anterior muscle is a respiratory support muscle, no significant decrease in vital capacity (VC) or forced expiratory volume in 1 second (FEV_1) was observed from before to after surgery, suggesting that the removal of the muscle flap had little effect on respiratory function (34). The serratus anterior muscles and latissimus dorsi muscle can be elevated simultaneously by using the common nutrient vessel, the thoracodorsal vessel branch (13), and radical cure of empyema after pneumonectomy with a combined latissimus dorsi—serratus anterior muscle flap has also been reported (16,35).

Rectus abdominis muscle

The nutrient vessels of the rectus abdominis muscle are the superior epigastric vessels that are continuous with the internal mammary artery and vein (13). This muscle flap is used mainly to fill the lower half of the thoracic cavity (30). Jiang *et al.* have successfully closed the empyema cavity in three patients with postoperative chronic empyema with bronchopleural fistula using a two-stage thoracoplasty with a free rectus abdominis muscle valve without the development of postoperative complications (36). The combination of a free rectus abdominis muscle flap and a pectoralis major muscle pedicle flap was effective for empyema following pneumonectomy with bronchopleural fistula (37).

Other muscles

Other muscles that could be used as muscle flaps include the trapezius, subscapularis, infraspinatus, external oblique, and teres major, but their use is rare. No significant experience with these muscles has been reported in the literature, and they should be considered only when the aforementioned common muscles are not available (25,38).

Treatment outcomes

Botianu *et al.* retrospectively analyzed 76 cases of chronic empyema, including 13 cases of post-pneumonectomy empyema (39). All patients underwent thoracoplasty and muscle flap filling, and a closed-circuit irrigation-aspiration system was used postoperatively for primary closure of the wound. A total of 148 flaps (60 serratus anterior, 55 latissimus dorsi, 27 pectoralis major, and 6 subscapularis) were created, with an average of 1.9 flaps per case. Mild shoulder joint dysfunction was observed in 5 patients, but no other serious local complications were noted. Comparison of VC and FEV_1 before and after surgery showed no significant differences, suggesting that the muscle flap harvest had little effect on respiratory function. Only 5% (n=4) required reoperation due to recurrent infection, and all patients were cured, with an overall mortality rate of 5% (n=4). The type of muscle flap used did not affect the outcome or postoperative respiratory function (39). Other reports (12,40-43) have also shown relatively good outcomes with thoracoplasty and muscle filling, with an overall mortality of approximately 5% and a success rate of more than 90% in cases in which the empyema was cured without recurrence.

Shinohara *et al.* (44) compared the outcomes with muscle flap and omental pedicle flap use in postoperative closure of the empyema cavity, and found that the mortality rate, complication rate, and success rate were comparable. However, the rate of local recurrence of infection in patients with bronchopleural fistula tended to be higher in cases of muscle flap use (44); Tseng *et al.* (45) and Farid *et al.* (46) postulated that disuse atrophy of the muscle occurs during the 5–6 weeks after muscle grafting, affecting recurrent infection. Omental pedicle flaps have anti-inflammatory properties and are believed to promote tissue healing due to the abundance of blood vessels and lymphatic vessels (47). In cases with bronchopleural fistula or refractory pulmonary fistula, these different properties should be taken into consideration, and filling materials should be chosen more carefully.

Conclusions

Combined thoracoplasty and muscle transposition is a technique that allows radical cure of refractory postoperative chronic empyema without lung resection or decortication. It is an important procedure that offers good functional and aesthetic recovery, and although it is performed infrequently, thoracic surgeons should be familiar with it.

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