Closure of bronchopleural fistula after pneumonectomy with a pedicled intercostal muscle flap

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Abstract

Objectives: The value of the pedicled intercostal muscle flap for the closure of postpneumonectomy bronchopleural fistulas was studied retrospectively. Methods: Bronchopleural fistula was suspected in case of fever, cough, putrid or haemorrhagic expectoration, in combination with a rise of WBC and CRP. Fistula diagnosis was established bronchoscopically. Two patients underwent an initial trial of bronchoscopic sealing, the rest were reoperated immediately after fistula diagnosis. Immediately after operation antibiotic irrigation according to culture sensitivity was started via a single chest tube drainage twice a day. After instillation of antibiotics the drain was kept clamped for 3 h. Culture samples were obtained twice a week. Empyema was considered eradicated, if three subsequent cultures showed no bacterial growth. After drain removal the patients were kept in hospital for another week and observed for clinical signs of infection, WBC and CRP were controlled. Age, side, sex, histology, TNM-stage, duration of hospital stay after fistula diagnosis (days), duration of treatment (defined as the duration of chest tube drainage in days after operation), total hospital stay (including the initial hospital stay for primary resection and the hospital stay for fistula treatment in case of readmission), fistula size (mm), interval (days) between primary operation and fistula formation, and bacteriology were recorded. Results: Eight patients (seven male) were treated. Age ranged from 46 to 70 years (mean 57.86). Six fistulas were located on the right side. All patients had non small cell lung cancer. Interval ranged from 2 to 72 days (mean 26.9 days). Fistula size ranged from 1 to 7 mm (mean 3.43). Seven fistulas were successfully closed. Duration of treatment lasted from 15 to 28 days in those patients treated successfully (mean 17). Hospital stay ranged from 15 to 31 days (mean 24.4). In one patient the flap became necrotic, he was successfully treated with total thoracoplasty. One patient died on the 38th day after rethoracotomy due to aspiration pneumonia. At postmortem examination the bronchial stump was closed. Conclusion: The use of the pedicled intercostal muscular flap is an efficient method for the closure of bronchopleural fistula after pneumonectomy. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Bronchopleural fistula; Pneumonectomy; Muscle flap; Intercostal; Empyema

1. Introduction

Bronchopleural fistula after pneumonectomy is a formidable complication in thoracic surgery. Mortality ranges from 30 to 70% and is a result of delayed diagnosis and treatment. In the past closure of the bronchial stump with various muscular flaps has been reported. Another option is bronchoscopic treatment with fibrin sealant or the use of the greater omentum. The use of the intercostal muscle flap, although being regarded as an established operative technique for the treatment of bronchopleural fistula, has surprisingly been reported only rarely in the literature [1,18,19]. We report our experience in eight patients suffering from bronchopleural fistula after pneumonectomy, who were treated with pedicled intercostal muscle flaps.

2. Patients and methods

Between 1995 and 1998 149 pneumonectomies (58 right sided, 91 left sided) were performed. Surgical access was gained via a posterolateral thoracotomy under antibiotic prophylaxis with a second generation cephalosporin. Depending on the surgeon’s personal preference the 6th rib was removed at thoracotomy. After complete lymphadenectomy the bronchial stump was routinely resected tangentially to the trachea and closed with a mechanical stapling device or with interrupted sutures (vicryl 4.0).
There was no routine coverage of the bronchial stump. Postoperative ventilation was not required. The chest tube was removed on the day following resection irrespective of the drainage volume.

Eight patients suffering from bronchopleural fistula were treated with an intercostal muscle flap and their hospital charts retrospectively reviewed. Age, side, sex, histology, TNM-stage, duration of hospital stay after fistula diagnosis (days), duration of treatment (defined as the duration of chest tube drainage in days after operation), fistula size (mm), interval between fistula formation and primary operation (days), and bacteriology were recorded.

Bronchopleural fistula was suspected in the presence of fever, cough, purulent or hemorrhagic expectoration, in combination with a rise of WBC and CRP. Fistula diagnosis was achieved by bronchoscopy in combination with fistulography in all cases. As soon as a fistula was suspected, a chest tube was reinserted and samples were taken for bacteriological cultures. Immediately after the diagnosis was established, operation was performed except in two patients, who underwent an initial trial of unsuccessful bronchoscopic closure with fibrin sealant. The thorax was reopened through the original intercostal space with the patient in the lateral decubitus position. The thoracic cavity was debrided, aspergillus cultures taken and the fistula dissected. On the right side the azygos vein was routinely dissected to gain a better access to the bronchial stump. Only in one case was the stump long enough to allow re-resection. In all other cases the leak was closed with interrupted sutures (vicryl 4.0). The closed stump was covered with saline and the endobronchial pressure increased to 40 cm PEEP to ensure air tightness.

Which intercostal space for the flap was chosen depended on the local situation resulting from rib resection, shrinkage of the chest cavity and reduction of the intercostal spaces due to scarring.

The periost was incised and separated in continuity with the underlying muscle along the rib margins. To preserve the intercostal neurovascular bundle, it was mobilised by blunt digital dissection from the posterior surface of the rib. The use of electrocautery was avoided. After separation of the rib was resected. The remaining soft tissue plane filling the intercostal space was separated from the adjoining ribs en bloc with the adjacent pleura. After ligation of the intercostal flap at its anterior extremity it was wrapped in a moist warm gauze. The parietal pleura was removed from the chest wall along the intended course of the intercostal flap. The flap was now positioned on the pleural defect and adjusted over the bronchial stump without tension or torsion. It was fixed to the bronchial stump thereby covering it to its full extent and additionally attached to the thoracic wall with interrupted sutures (vicryl 3.0) to prevent the creation of dead space between flap and thorax wall.

At the end of the procedure the entire thoracic cavity was irrigated with 1000 ml of 0.1% Chloramin and a chest drain inserted at the most caudal point of the thoracic cavity. In the ward the empty hemithorax was irrigated with antibiotic solution via the chest tube according to culture results twice a day. After instillation the drain was clamped for 3 h and the patient, if capable, was encouraged to leave the bed. Cultures were obtained twice a week. After three consecutive negative cultures the infection was considered eradicated and the drain was removed. Thereafter the patients were kept in hospital for another week, CRP and WBC were controlled regularly. If there were no clinical signs of infection or fistula recurrence and the blood results were within the normal levels, the patient was discharged and the intervention considered successful.

One patient died on the 38th postoperative day due to aspiration pneumonia. At postmortem examination the bronchial stump was removed together with the adherent intercostal flap and fixed in formalin. For histological exam-

### Table 1

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Side</th>
<th>Age</th>
<th>Histology</th>
<th>Stage</th>
<th>Bronchial closure</th>
<th>Rib resection (at primary operation)</th>
<th>Intercostal flap size (mm)</th>
<th>Interval (days)</th>
<th>Bacteriology</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.A.</td>
<td>M</td>
<td>R</td>
<td>70</td>
<td>Adenocarcinoma</td>
<td>t2n2</td>
<td>Vicryl⁴</td>
<td>No</td>
<td>4th and 5th rib</td>
<td>7</td>
<td>No germ isolated</td>
</tr>
<tr>
<td>Z.M.</td>
<td>F</td>
<td>R</td>
<td>48</td>
<td>Adenocarcinoma</td>
<td>t2n2</td>
<td>Vicryl⁴</td>
<td>No</td>
<td>5th and 6th rib</td>
<td>1</td>
<td>No germ isolated</td>
</tr>
<tr>
<td>H.F.</td>
<td>M</td>
<td>R</td>
<td>69</td>
<td>Squamous cell carcinoma</td>
<td>t2n2</td>
<td>Stapler</td>
<td>6th rib</td>
<td>7th and 8th rib</td>
<td>2</td>
<td>No germ isolated</td>
</tr>
<tr>
<td>B.U.</td>
<td>M</td>
<td>L</td>
<td>58</td>
<td>Squamous cell carcinoma</td>
<td>t2n0</td>
<td>Vicryl⁴</td>
<td>No</td>
<td>6th rib</td>
<td>4</td>
<td>Pseud. aeruginosa</td>
</tr>
<tr>
<td>R.P.</td>
<td>M</td>
<td>R</td>
<td>64</td>
<td>Squamous cell carcinoma</td>
<td>t3n2</td>
<td>Stapler</td>
<td>6th rib</td>
<td>4th and 5th rib</td>
<td>6</td>
<td>E. coli</td>
</tr>
<tr>
<td>B.M.</td>
<td>M</td>
<td>R</td>
<td>46</td>
<td>Squamous cell carcinoma</td>
<td>t2n1</td>
<td>Stapler</td>
<td>6th rib</td>
<td>4th rib</td>
<td>1</td>
<td>Strep. viridans</td>
</tr>
<tr>
<td>G.P.</td>
<td>M</td>
<td>L</td>
<td>58</td>
<td>Large cell carcinoma</td>
<td>t2n0</td>
<td>Stapler</td>
<td>6th rib</td>
<td>6th and 7th rib</td>
<td>3</td>
<td>Strep. viridans</td>
</tr>
<tr>
<td>M.D.</td>
<td>M</td>
<td>R</td>
<td>50</td>
<td>Squamous cell carcinoma</td>
<td>t2n0</td>
<td>Stapler</td>
<td>6th rib</td>
<td>8th rib</td>
<td>3</td>
<td>Staph. aureus</td>
</tr>
</tbody>
</table>

⁴ Hand sewn interrupted sutures, vicryl 4.0.
ination the region of interest was dehydrated and embedded in paraffin. The tissue sections (two micron thickness) were stained with Hematoxylin-Eosin (HE).

3. Results

Eight patients (seven males) were treated. Their relevant data are shown in Table 1. Age ranged from 46 to 70 years (mean 57.86), all suffered from non-small cell lung cancer, there were five squamous cell carcinomas, one large cell carcinoma and two adenocarcinomas. In four cases bronchial stump insufficiency occurred during the initial hospital stay. Their total hospital time was 33–114 days (mean 58) (Table 2). The other four patients were discharged from hospital after an uneventful postoperative course after 13–19 days (mean 17 days) and readmitted after 11–108 days (mean 53.5 days). Their total hospital time including fistula repair was 32–47 days (mean 38 days).

The fistulas occurred between the second and the 127th day after pneumonectomy (mean 26.9 days) and were located on the right side in six cases. Fistula size at primary bronchoscopy ranged from 1 (pinhole fistulas, proven with fistulography) to 7 mm (mean 3.43 mm).

At the original operation the sixth rib had been removed in five patients, the bronchial stump had been closed with a mechanical stapling device in five cases, with interrupted sutures (vicryl 4.0) in three. Only in one patient was the bronchial stump still long enough to allow re-resection. In six cases the leak was closed with interrupted vicryl sutures (4.0) without refreshing the stump. In one patient the leak could not be closed successfully with sutures. It was directly covered with the muscle flap.

In five cases (three after resection of the 6th rib) the muscular flap was derived from two adjacent intercostal spaces. In the remaining three patients the muscles of a single intercostal space were used. Which flap was chosen in each patient is shown in Table 1.

One patient required four blood units during the first 3 postoperative weeks. Duration of treatment after operation ranged from 15 to 28 days in those patients treated successfully (mean 17). Their hospital stay ranged from 15 to 31 days (mean 24.4 days). Six patients were treated successfully. They had an uneventful postoperative course and were discharged from hospital with the fistula closed and the empyema eradicated. One of these patients (G.P.) suffering from a left sided fistula underwent two futile trials of bronchoscopic sealing before muscle flap closure took place. The fistula recurred 5 and 7 days after fibrin instillation finally making operative intervention eventually necessary. Reintervention thus took place 13 days after fistula diagnosis. However, during this time of temporary air tightness, postpneumonectomy empyema was successfully eradicated by pleural rinsing, allowing the chest tube to be removed eight days after reoperation.

There were two treatment failures. One patient died from aspiration pneumonia acquired preoperatively, before fistula diagnosis was established, representing a mortality of 12%. Due to respiratory failure he underwent mechanical ventilation postoperatively and died on the 38th day after stump coverage. At autopsy the gross examination revealed chronic pleural empyema, pneumonia, signs of sepsis, and a closed bronchial stump although empyema was still active (Pseudomonas spp). Histology proved that the muscular tissue was viable and in tight contact (complete integration and healing) with the bronchial cartilage, thus covering the entire resection area of the stump (Fig. 1). The interface of the bronchial wall and the intercostal muscle was formed by reparative tissue with vascular colonisation (Fig. 1b, enlargement of the left upper corner of Fig. 1a). Areas of the skeletal muscle showed mild to moderate signs of atrophy with consecutive fibrosis and incipient scar formation. Inflammatory changes were within the normal range of reparative processes. Necrotic areas were not found. The histological changes described are confirmed in the literature [14].

The second patient refused immediate thoracotomy after fistula diagnosis and only accepted a trial of bronchoscopic sealing. Although being informed that in his case this modality was not the treatment of choice due to an atrophic, badly perfused mucosa of the bronchial stump, the patient did not consent to operation. As expected,

<table>
<thead>
<tr>
<th>Patient</th>
<th>Interval (days)</th>
<th>Duration of treatment (days)</th>
<th>Initial hospital stay after pneumonectomy (days)</th>
<th>Hospital stay after muscle flap closure (days)</th>
<th>Total hospital stay</th>
<th>Followup (days)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.A.</td>
<td>31</td>
<td>17</td>
<td>19</td>
<td>28</td>
<td>47</td>
<td>403</td>
<td>Died</td>
</tr>
<tr>
<td>Z.M</td>
<td>72</td>
<td>8</td>
<td>17</td>
<td>15</td>
<td>40</td>
<td>1188</td>
<td>Alive</td>
</tr>
<tr>
<td>B.M.</td>
<td>53</td>
<td>20</td>
<td>13</td>
<td>27</td>
<td>40</td>
<td>416</td>
<td>Alive</td>
</tr>
<tr>
<td>G.P.</td>
<td>127</td>
<td>8</td>
<td>19</td>
<td>14</td>
<td>33</td>
<td>245</td>
<td>Alive</td>
</tr>
<tr>
<td>M.D.</td>
<td>2</td>
<td>Thoraco-plasty</td>
<td>–</td>
<td>114</td>
<td>114</td>
<td>326</td>
<td>Alive</td>
</tr>
<tr>
<td>H.F.</td>
<td>3</td>
<td>38</td>
<td>–</td>
<td>38</td>
<td>41</td>
<td>38</td>
<td>Died</td>
</tr>
<tr>
<td>B.U.</td>
<td>16</td>
<td>25</td>
<td>–</td>
<td>31</td>
<td>47</td>
<td>1116</td>
<td>Alive</td>
</tr>
<tr>
<td>R.P.</td>
<td>11</td>
<td>15</td>
<td>–</td>
<td>21</td>
<td>32</td>
<td>440</td>
<td>Alive</td>
</tr>
</tbody>
</table>
bronchoscopic sealing failed resulting in fistula recurrence the following day. Within this short period of 24 h he developed aspiration pneumonia requiring immediate mechanical ventilation. After obtaining informed consent from his relatives thoracotomy was now performed and the fistula closed with an intercostal flap. Two new fistulas occurred at different positions of the bronchial stump on the 10th and the 12th postoperative days after muscle flap closure. Due to initial revascularisation originating from the overlying muscle they were successfully treated with submucosal fibrin injection. However, when a new fistula occurred on the 19th postoperative day, we decided to perform a total thoracoplasty. At reoperation the intercostal flap turned out to be completely necrotic, half of the diameter of the bronchial stump was dehiscent. During the initial postoperative period after thoracoplasty the leakage still increased, suggesting that total stump necrosis had developed. The patient was extubated and stayed in hospital for another 3 months until the bronchial stump was finally closed by the formation of granulation tissue supplied by the overlying muscles. He was discharged with a permanent drainage, which was removed 42 days later.

During the observation period (245–1188 days, mean 590.6) one patient died of distant tumour recurrence on the 403th day after muscle flap closure. No fistula or empyema recurrence were observed.

4. Discussion

The use of the intercostal muscle is an old and well tried surgical principle. It was first described by Penton et al. in 1951 based on animal experiments [2]. Their findings were confirmed by Michelson et al. [3] and later by Grillo [4,5].

Since then it has been successfully utilised in the treatment of tracheoesophageal fistulas and esophageal perforations in adults [6], as well as in the paediatric age group [7,8], in plastic surgery for reconstruction of a wide variety of torso defects [9] and even for the closure of a persistent intrapleural-dural cerebrospinal fluid fistula in a child [10].

While the successful use for prophylaxis against bronchopleural fistula after pulmonary resections has been repeatedly reported [11,12], the closure of a bronchopleural fistula after pneumonectomy with a pedicled intercostal muscle flap still remains a controversial issue in the literature, although it appears to be an ideal flap for tracheobronchial reconstruction; the intercostal flap has the advantage of a multiplicity of uses and of considerable motility, reaching virtually every part of the thorax. The pleura covering of the intercostal muscle provides an epithelial surface at the site of the tracheal or bronchial repair. In an animal study the posterior wall of the trachea and the bronchi showed impermeability and rapid healing at bronchoscopy on the 10th day after reconstruction with an intercostal flap as well as regeneration of the ciliated epithelium [13]. Bronchial revascularisation by capillary ingrowth from the pedicle to the bronchial submucosal plexus was demonstrated in animals [14]. Rendina et al. [12] demonstrated by selective angiography that within 7 days after sleeve resection with the anastomosis reinforced by intercostal flaps, a fine vascular network surrounding the anastomosis had built up. Even in cases of anastomotic dehiscence the airway continuity was maintained by the flap, its pleural surface being visible endoscopically through the anastomotic leak [12]. Although it has been critically mentioned that bone formation originating from the periost of the flap with consecutive stenosis of the wrapped bronchial anastomoses can occur, only very few complications resulting from that biological behaviour have been reported [15].

The current literature simply favours omentoplasty or the use of extrathoracic muscles for the treatment of postpneumonectomy bronchopleural fistula [16–18].

Although being an accepted surgical technique, the closure of postpneumonectomy BPF with intercostal flaps remains sparsely reported in the literature and the published results are frustrating. Mineo et al. [1] reported a recurrence
rate of 66% in a series of six patients, concluding that a
diaphragmatic flap was superior. Kalweit et al. [18] describe
25 patients treated with a pedicled intercostal muscular flap or
pericardial tissue. Both operative techniques are
summarised in one group. In five cases closure of the fistula
was impossible, making an immediate switch to total thor-
acooplasty necessary. Of the remaining 20 cases, definitely
treated with an intercostal or pericardial flap, eight died
during the early postoperative period. Five patients devel-
oped a fistula recurrence, which was treated with total thor-
acooplasty. The overall mortality was 50%. Unfortunately
the exact number of patients treated with an intercostal
flap and their postoperative course is not mentioned sepa-
rately [18]. Barker et al. [19] presented only one successful
case and concluded that full thickness intercostal muscle
grafts are ideal for early closure repair and support of fistu-
las following pneumonectomy. Other authors regard the
dissection of the pedicled graft as difficult compared with
other surgical options [20]. Michaels et al. [21] state that not
only closure of the bronchial stump but additional reduction
of the postpneumonectomy space are crucial for control of
the concomitant postpneumonectomy empyema and thus
prefer muscular flaps with a greater volume.

In our experience the use of a pedicled intercostal flap has
proven to be successful in the majority of cases. The mortal-
ity of 12% is acceptable and compares favourably with the
literature. The death of one patient has to be attributed to
delayed diagnosis with consecutive aspiration. Aspiration
pneumonia remains the most dangerous complication in
patients with early postpneumonectomy BPF, almost inevi-
tably resulting in lethal ARDS if not prevented by immedi-
ate thoracic drainage, endoscopy or reoperation. Isolation of
the intercostal muscle from the adjacent rib should be a
standard procedure for the thoracic surgeon, since he is
familiar with the technique of rib resection. The dissection
of the flap proved to be rather simple, though care has to be
taken not to injure the neurovascular bundle. However, the
procedure can be technically demanding in the upper region
of the thorax and in cases of a late fistula with extensive
fibrosis of the hemithorax. If the thoracic wall is fibrotic the
consistence of the flap is raised, resulting in reduced mo-
Bility and the shortest distance must be chosen. Thus in those
cases the flap must be isolated from a rib at the same level as
the fistula even if an adjacent rib has been resected at the
initial operation. In our series the muscular flap was
harvested from two adjacent intercostal spaces, when a rib
had been removed at the primary operation. In these cases
previous rib resection did not adversely affect the outcome.

We believe that the fixation of the entire flap to the thor-
acic wall is crucial. It allows vascularisation in both direc-
tions and prevents fluid collection between the flap and the
chest wall, which could result in abscess formation.

In one case the flap turned necrotic. This patient was
young and suffered from no additional risk factors or ather-
osclerosis, which could provide an explanation for an early
occlusion of the intercostal artery.

During the postoperative hospital stay we did not observe
any patient, in whom the pleural cavity became obliterated.
Serothorax developed after discharge from hospital, leading
in the majority of cases to fibrothorax. To date no fistula
recurrence has been observed. We have confidence in the
natural organising process of obliteration, which can be
expected if the causative infection is eradicated. Therefore
we refrain from surgical reduction of the postpneumonec-
tomy space.

5. Conclusion

Closure of bronchopleural fistula after pneumonectomy
with a pedicled intercostal flap has proven to be a well
tolerated procedure and is as efficient as any other muscular
flap used for closure of bronchopleural fistulas. Thus the
intercostal flap should become part of the basic repertoire
of techniques used by every thoracic surgeon, who is
required to face the problem of bronchopleural fistula as
part of a daily routine.

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