Accelerated treatment of postpneumonectomy empyema: A binational long-term study

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Objective: Postpneumonectomy empyema remains a clinical challenge. We proposed an accelerated therapy without an open chest window 5 years ago. This concept was evaluated on a larger scale in 2 centers in 2 different countries.

Methods: Between July 1995 and October 2005, 75 consecutive patients with post-pneumonectomy empyema were treated in Szczecin, Poland (n = 35), and Zurich, Switzerland (n = 40). The therapy consisted of repeated open surgical debridement of the pleural cavity after achievement of general anesthesia, a negative pressure wound therapy of the temporarily closed chest cavity filled with povidone-iodine-soaked towels, and continuous suction and systemic antimicrobial therapy. If present, bronchopleural fistulae were closed and reinforced either with a muscle flap or the omentum. Finally, the pleural space was filled with an antibiotic solution and definitively closed.

Results: Of 75 patients (63 men; median age, 59 years; age range, 19–82 years), post-pneumonectomy empyema was present on the right in 46 patients (32 with bronchopleural fistula) and in 29 patients (12 with bronchopleural fistula) on the left. Median time between pneumonectomy and postpneumonectomy empyema was 131 days (range, 7–7200 days). Bronchopleural fistulae have been closed and additionally reinforced by means of different methods (omentum, 18; muscle, 11; pericardial fat, 5; azygos vein, 1). The chest was definitively closed within 8 days in 94.6% of patients. The median hospitalization time was 18 days (range, 9–134 days). Postpneumonectomy empyema was successfully treated in 97.3% of patients, including 10 (13%) patients who needed a second treatment cycle. Three (4%) patients died within 90 days. The median follow-up time was 29.5 months (range, 3–107 months).

Conclusions: Treatment of postpneumonectomy empyema with the accelerated treatment is effective and safe. Our results are superior compared with those in reported series using a (temporary) chest fenestration. Patients appreciate the physical integrity of the chest.

Treatment of postpneumonectomy empyema (PPE) remains a serious problem, with a reported mortality of up to 10% to 20% and a failure rate with persistently open window thoracostomy of 20% or more, even in recent reports.^{1–4} Recommended procedures include a wide spectrum from single-stage lavage performed by means of video-assisted thoracoscopy for early empyemas to repeated cleaning of the cavity through a temporary or persistently open window thoracostomy and various modifications for different empyema stages. Furthermore, transposition

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Abbreviations and Acronyms

BPF = bronchopleural fistula

PPE = postpneumonectomy empyema

of muscles into the chest or thoracoplastic procedures to obliterate the thoracic cavity are applied.

The problem of PPE is presented by the large size of the infected noncollapsible chest cavity, which is filled with pus and covered by poorly vascularized infected tissue. The surgical principles of treatment for infected spaces have been well known since the early time of medicine and includes evacuation of pus and debridement of the infected tissue combined with obliteration, marsupialization, or opening of the infected cavity. These principles were applied for therapy of PPE over the last 50 years when various treatment concepts were developed. For palliative situations in critically ill and polymorbid patients, a drainage alone or drainage followed by a permanently open chest window for irrigation was or still is the treatment of first choice in some centers. However, the open window thoracostomy is not well accepted by patients and interferes with their quality of life. Consequent surgical debridement in combination with systemic antibiotic therapy is necessary to achieve an infection-free closed chest. PPEs are often associated with a bronchopleural fistula (BPF), which further complicates the situation. For successful therapy, the open bronchial stump has to be closed and reinforced with well-vascularized tissue.⁵ During the last 2 decades, the concept of the open chest window first described by Clagett and Geraci⁶ was modified, especially by Pairolero and colleagues from the Mayo clinic in Rochester, Minnesota.^{1,3,4,7,8} However, the course of treatment is usually long, and during this time, patients have to deal with an open chest window in their body. Furthermore, the open chest window remains life-long in up to one third of their patients.²

In 1995, we were contacted by a 25-year-old woman with a left-sided PPE without a BPF for more than 10 years after a pneumonectomy for unilobar bronchiectasis that was performed elsewhere. The cavity was infected with *Pseudomonas* species, and the pus drained itself over several submammary fistulas. During the last years, she underwent multiple treatment attempts with drains and lavage over months but refused to undergo an open chest window or a thoracoplastic procedure, which was recommended to her. We applied, for the first time, an accelerated treatment concept for chronic PPE in which we performed repeated scheduled mechanical debridement and packing of the pleural cavity with povidone-iodine-soaked dressings and closed the chest temporarily after each session. Surprisingly, we were able to finally close the chest within 10 days, and despite a subcutaneous abscess, which was easy to treat, she

remained infection free since then. This experience encouraged us to apply this concept consecutively in all patients with PPE, even in the presence of BPFs. The results of the first experience with 20 consecutive patients were published in 2001.⁷ Supported by our results and the positive experiences reported to us from colleagues in other institutions and countries who applied our concept, this approach became the treatment of choice for all patients with PPE, even those patients after an extrapleural pneumonectomy.

To prove the reproducibility and efficacy of this treatment, we included the experience of the members of the Thoracic Surgery Department of Pomeranian Medical University in Szczecin, Poland, who applied the same approach in a standardized fashion to their patients after a visit to our institution in 1998 and report them here.

Materials and Methods

From July 1995 through October 2005, 75 consecutive patients with early (n = 30) and late (n = 45) PPE were operated on at Pomeranian Medical University in Szczecin, Poland (since 1998), and at the division of thoracic surgery of the University Hospital of Zurich, Switzerland. We defined late PPE as the time of occurrence of PPE more than 90 days after pneumonectomy. Twenty-four patients were referred to us after 1 or several unsuccessful surgical attempts elsewhere. Thirty-five patients have been treated in Szczecin, and 40 patients have been treated in Zurich. Patients and results are described as 1 cohort independent from the site of treatment because the characteristics of both groups are comparable (Table 1).

Symptoms at admission included malaise, fever, and occasionally cough. BPF was mostly associated with position-dependent expectoration of serosanguinous or purulent sputum. On chest radiographic analysis, a mediastinal shift to the contralateral side might have been present, especially in early PPE. BPF was associated with lowering of the fluid level in the postpneumonectomy space. Every patient was evaluated with a chest computed tomographic scan, as well as bronchoscopy, when a BPF was suspected either on clinical or radiologic signs. If BPF was suspected, chest tube thoracostomy was performed to avoid contamination of the remaining lung and for repositioning of the mediastinum. The diagnosis of empyema was based on clinical signs, radiologic features (eg, contrast enhancement of the pleura on chest computed tomographic scan), and the macroscopic appearance (pus), pH (<7.25), and microbiologic results from the pleural fluid. Patients with early PPE typically had fever, malaise, thoracic pain, and dyspnea. In contrast, patients with late PPE showed more a pattern of chronic infection most commonly with mild malaise and anorexia and often without fever. Broad-spectrum antimicrobial therapy (culture specific) was administered at least 24 to 48 hours before surgical revision.

Results of bacteriology of the pleural cavity were found to be positive in 50 (66.6%) patients for 1 or several microorganisms, including fungi in 9 cases (*Candida albicans*, n = 5; *Aspergillus* species, n = 4; Table 2).

The most common indication for pneumonectomy was non-small lung cancer (n = 61, 81.3%), followed by different benign pathologies (n = 7, 9.3%), mesothelioma (n = 5, 6.7%), and other malignant diseases (n = 2, 2.7%). Of the 70 patients operated on for a malignancy, 36 (51.4%) had either neoadjuvant or adjuvant

TABLE 1. Comparison of patients' characteristics between the 2 centers

Observation period	Zurich, Switzerland	Szczecin, Poland
	July 1995–October 2005	January 1998–January 2005
No. of pneumonectomies	447	708
Age, y (median/range)	59 (23–82)	60 (19–80)
Women/men	6/34	6/29
PPE in own institution/referred	20/20	31/4
Incidence of PPE, %	4.47	4.43
Side right/left	28/12	18/17
BPF right/left	24/5	8/7
Indication for pneumonectomy		
NSCLC	29	32
Mesothelioma	4	1
Other disease	7	2
Early PPE (<90 d)	24	6
Late PPE (>90 d)	16	29

PPE, Postpneumonectomy empyema; BPF, bronchopleural fistula; NSCLC, non-small cell lung carcinoma.

chemotherapy (14 neoadjuvant/2 adjuvant), radiotherapy (2 neoadjuvant/12 adjuvant), or both (1 neoadjuvant/5 adjuvant) before the onset of PPE. All 5 patients with malignant mesothelioma were treated with induction chemotherapy before the extrapleural pneumonectomy. The pericardium was reconstructed with xenopericard (PERI-Guard, Synovis) and the diaphragm with Mersilene-Mesh (Ethicon).

Forty-six (61.3%) patients had a right-sided PPE, 4 of them after a right-sided pleuropneumonectomy and 29 (38.6%) after left-sided resections (1 after a pleuropneumonectomy). Of the 7 patients with benign disease, 4 were operated on for a destroyed lung because of tuberculosis and 2 for major hemoptoe (1 because of severe bronchiectasis), and 1 had a large hamartoma of the central airways that was otherwise not resectable.

The operative technique⁷ includes repeated surgical debridement of the chest cavity after achievement of general anesthesia every 48 hours with temporary closure of the chest, which is filled with povidone-iodine-soaked towels, and finally obliteration of the cavity with an antibiotic solution.

In detail, patients are intubated with a double-lumen endotracheal tube to protect the contralateral lung until a BPF is definitively ruled out. The previous thoracotomy (generally an anterolateral incision) is reopened, paying attention not to harm the soft tissue. A radical debridement of the pleural cavity is performed by means of parietal pleurectomy if possible and/or curettage of all necrotic and fibrinous infected tissue from the chest wall and diaphragm with a sharp spoon and/or sponges on the mediastinum followed by irrigation with diluted povidone-iodine solution (1:10). The debridement on the mediastinum must be carried out carefully to avoid injury of the hilar structures, especially when curettage is used. The presence of a small BPF is usually confirmed by flooding the chest cavity with saline and observing escaping air bubbles from the hole in the bronchial stump. Various techniques for closure are applied

TABLE 2. Preoperatively assessed microbiology (culture) of pleural fluid

Patients with positive bacteriology	50 (66.6%)
Gram-positive germs	<i>Staphylococcus</i> species (SKN) 20 (14)
	<i>Streptococcus</i> species 14
	Other 9
Gram-negative germs	<i>Pseudomonas</i> species 10
	<i>Serratia</i> species 6
	Other 11
Fungi	<i>Candida albicans</i> 5
	<i>Aspergillus</i> species 4

depending on the size of the hole, the length of the bronchus, the quality of the bronchial wall, and its fixation in the mediastinum. In case of a long bronchial stump, the bronchus is shortened and closed by means of stapling or suturing. In short stumps closure techniques vary again based on the size of the hole and the condition of the surrounding tissue. When applicable, the BPF is closed with direct interrupted sutures (3-0 or 4-0 PDS sutures) and reinforced with a muscle flap or omentum. In large bronchial holes in a short stump or a bronchus, which can be fixed in the mediastinum, direct closure of the BPF is not feasible. This is typically the case in late-occurring and chronic empyemas. In these situations we close the bronchial opening with a parachute technique, preferentially using the omentum pedicle as a patch. The pedicle is placed on the stump without tension to cover the opening and is fixed with interrupted 4-0 PDS sutures to achieve an airtight closure. The packing with povidone-iodine-soaked towels applies the necessary counterpressure during coughing until the omentum or muscle is adherent to the mediastinum.

To expose the omentum, a short upper midline incision is performed, and the omentum is freed from the transverse colon and mesocolon and dissected from the stomach along the greater curvature. Pediculated on the right gastroepiploic artery, it is brought into the pleural cavity through a substernal tunnel. By placing the omentum into the thorax, the pedicle of the omentum must not be twisted, and the diameter of the tunnel should be large enough to maintain vascular flow but small enough to avoid herniation of abdominal organs. The omentum is then sutured with interrupted sutures on the bronchial stump. In addition, the omentum is fixed to the mediastinum.

At the end of every surgical intervention (with or without BPF) but before the definitive closure, the pleural cavity is packed with dressings soaked with povidone-iodine solution (diluted 10:1), carefully avoiding a mediastinal shift through overstuffing the thoracic cavity. A chest tube on 5 to 10 cm H₂O suction is placed between the chest wall and towels to apply as a negative pressure wound therapy and to avoid overfilling of the cavity with reactive effusion and to protect the soft tissue from the potential contaminated intrathoracic fluid. The thoracotomy is temporarily closed by adapting the ribs with 3 to 4 interrupted sutures and a running suture of the fascia and closure of the skin with clips. The patient is extubated and mobilized out of bed. Preferentially, he or she is walking around on the regular ward between interventions. Every 48 hours, the antiseptic packings are changed, and the surgical debridement, using curettage mainly, is repeated in the operating

TABLE 3. Outcome of the whole cohort of patients compared between the 2 centers

	Zurich, Switzerland	Szczecin, Poland	Whole cohort
Success rate after first treatment	n = 36; 90%	n = 29; 82.9%	n = 65; 86.7%
Recurrence rate	n = 4; 10%	n = 6; 17.1%	n = 10; 13.3
Overall success rate (including second attempt)	n = 39; 97.5%	n = 34; 97.1%	n = 73; 97.3%
30-d Mortality	n = 1; 2.5%	n = 0	n = 1; 1.3%
90-d Mortality	n = 1; 2.5%	n = 1; 2.8%	n = 2; 2.7%
Closed chest	n = 39*; 97.5%	n = 35†; 100%	

*One patient died before treatment was completed. †One patient remained a "drain carrier."

theater after achievement of general anesthesia until the chest cavity is macroscopically clean. Finally, the pleural space is obliterated with an antibiotic solution, and the thoracotomy is definitively closed watertight.

The composition of the antibiotic solution depends on the microbiologic findings. Typically, it consists of 0.3 g of netilmicin, 2.2 g of ampicillin/clavulanic acid, and 1.0 g of vancomycin per liter of saline. Depending on the resistance of the germ, accessory antibiotic agents or fungicides (0.4 g of fluconazol or 1 mg/kg amphotericin) were added to the solution.

The preoperatively started parenteral antibiotic treatment is continued.

BPF is closed during the first attempt if possible to avoid contamination of the contralateral lung, especially if the hole is large. In some situations with pinhole lesions and advanced empyemas, it seemed to be advantageous to achieve a clean chest and mediastinum first, and therefore closure and reinforcement of the BPF is done during the second intervention.

At final closure of the rib cage, the muscle layers (m. pectoralis major and m. serratus) and the subcutaneous tissue are closed with running sutures.

Results

There were 75 patients (63 men and 12 women) with a median age of 59 years (range, 19–82 years). The median time interval between pneumonectomy and diagnosis of PPE was 131 days (range, 7–7200 days). In 45 (60%) of the patients, the described treatment of PPE was more than 90 days after pneumonectomy, with a median time of 181 days and a range of 107 days to 19.7 years (7200 days) after primary intervention. Thirty patients showed an early PPE with a median time interval of 36 days (range, 7–89 days). In 5 patients the empyema was already present at the time of pneumonectomy. In 49 (65.3%) patients either chest tube drainage (n = 37, 49.3%) was performed initially or a puncture (n = 12, 16%) of the pleural cavity was performed to confirm the diagnosis. The remaining 26 patients were operated on directly. BPF was present in 44 (58.6%) patients, 24 times in patients with late (>90 days after pneumonectomy) and 20 times in patients with early PPE. The fistula occurred on the right side in 32 (72.3%) patients and on the left side in 12 patients (Table 3).

In 9 of the 44 patients with BPF, a pinhole fistula in the staple line was found, and the bronchial stump was sutured and protected with surrounding tissue only without reinforce-

ment with muscle or omentum. In the remaining 35 patients, the bronchial stump was closed with sutures and reinforced with omentum (n = 18), muscle flap (n = 11), and pericardial fat (n = 6). In 5 patients a direct closure of the bronchial fistula was not possible because of the large size of the hole and the scarring of the surrounding mediastinal tissue. The omentum was sutured directly on the bronchial wall to close the hole. In Zurich the omentum was used as the first choice to reinforce the bronchial stump. No complications from the abdomen, especially no peritonitis or wound infections, were observed. In Szczecin muscle flaps were favored with comparable results.

The median number of interventions until final closure of the chest, including the first rethoracotomy, was 3 (range, 1–8). In 2 early PPEs without fibrinopurulent secretion, the chest was rinsed with diluted povidone-iodine and definitively closed after filling the cavity with an antibiotic solution in one intervention. On the other extreme, 8 attempts were needed to achieve a macroscopically clean pleural cavity, as well as a sufficiently adherent omentum, to cover the bronchus and the mediastinum in 2 patients with a large bronchial stump insufficiency. In both cases, not only bacteria but also fungi in the necrotic tissue (*Aspergillus fumigatus* and *Candida albicans*) were cultured. Therefore debridement was repeated until no fungal growth was found in the chest. However, in the majority of cases, 3 interventions were required to obtain a macroscopically clean chest with healthy tissue and some granulation tissue, which allowed definitive closing of the chest. In 94.6% (71/75) of patients, no more than 4 interventions were needed, and the chest was definitively closed within 8 days.

The median hospitalization time was 18 days (range, 9–134 days), and the median time interval between final chest closure and discharge was 13 days (range, 3–83 days). The relatively long hospitalization time after definitive closure of the chest has 2 reasons. First, patients receive intravenous antibiotics for at least 1 week after closure of the chest, and intravenous medication is administered in hospitals or rehabilitation centers only. Second, patients in Europe often intend to stay in the hospital until full mobilization is achieved and they are able to go home directly.

The follow-up time ranged from 3 months to 8 years, with a median time of 29.5 months. At follow-up, 42 patients were alive, 30 died, and 3 were lost to follow-up. Of the deceased

patients, 29 had malignant disease, and 17 died because of tumor progression. Of the other 13 patients, 6 died of cardiac failure and 2 died of pulmonary embolism, and in 5 patients the reason for death was unclear. Three (4%) patients died during the hospitalization. One patient died 117 days after PPE treatment of the resected native lung because of graft failure after unilateral lung transplantation performed previously. One patient died of massive gastrointestinal bleeding on postoperative day 23, and 1 died of unrecognized repeat pulmonary embolism on postoperative day 82.

In 10 (13.9%) patients the empyema relapsed, in 6 of them because of detection of an overseen BPF or a recurrence between postoperative days 3 and 315. In 1 patient the fluid level in the pleural cavity decreased on day 3 after closure of the chest because a tiny BPF was missed during the initial treatment despite bronchoscopic examination and intraoperative underwater testing. In 1 patient the cause of recurrence was a gastroesophageal fistula (postoperative day 47), and in the remaining patient the reason was unknown. In 4 patients the described procedure was repeated with success. In another 4 patients a thoracomyoplasty was performed in Szczecin. All recovered well, with no signs of recurrence. Two patients refused further hospitalization for surgical revision; one is a “drain carrier” at the moment.

Two patients had subcutaneous wound infections that healed spontaneously.

Discussion

PPE is a rare complication, with an incidence of 4% to 5% in this report, but it has occurred even more frequently in other series.⁸⁻¹¹ The mortality and especially the morbidity are reported to be high.¹⁻⁴ Various treatments have been proposed, and their practicality depends on the stage of the empyema, the presence of a bronchial stump insufficiency, and the overall condition of the patient. We report on 75 patients with early and late PPE that are treated according to the rules of surgical treatment of an infected space, which includes debridement and cleaning of the infected area and final obliteration of the cavity by filling in an antibiotic solution.

The consequent application repeated debridement after achievement of general anesthesia in the operating theater, together with an appropriate antibiotic therapy, leads to a very high success rate of 97% and a low mortality rate of 4%. The insertion of povidone-iodine-soaked dressings in the chest with a drainage and negative pressure of 5 to 10 cm H₂O might additionally support the treatment by acting as a negative pressure wound therapy concept.^{12,13} The patients appreciate having their chests closed generally within a week and being without a drain or a temporary or final chest wall window.

The accelerated treatment is well tolerated, despite several interventions within a short period of time, probably because the repeated procedures are short in length and the patients are mobilized between these interventions. The majority of the de-

scribed patients had a late and established empyema, or the empyema was complicated with a bronchial stump insufficiency. Several of them had unsuccessful surgical treatments elsewhere. Taking these aspects into account, the reported treatment seems to be particularly effective and justified.

After having started this concept more than 10 years ago in Zurich, Switzerland, it was applied with comparable success in Szczecin, Poland. Furthermore, many surgeons from different countries reported to us their successful experiences. The concept might be considered an advancement of the procedure originally described by Clagett and Geraci⁵ and later modified by Pairolero and associates. The modified concept used at the Mayo Clinic in Rochester, Minnesota, consists of a temporary thoracostomy (Clagett window) and repeated changing of dressings in the patient's room or as an outpatient. Zaheer and associates¹ recently reported in a series of 84 patients that the initial closure of the chest before hospital discharge failed in 19%, and after a second Clagett procedure, 88% of all patients had their chest walls successfully closed. Eight (9.5%) patients had to live with a permanent thoracic wall defect. BPF healing was achieved in all 55 patients. However, the recurrence rate after the first attempt was 18%, and that after the second attempt was 5%. Perioperative mortality in their series was 7.1%.

In our series with comparable patients' characteristics and a similar incidence of BPF, the mortality was lower, and all our patients had a closed chest at hospital discharge. Of the 10 (13.3%) patients with a recurrence of PPE, 6 had either chemotherapy, radiotherapy (44–56 Gy), or both previously. In Zurich we reapplied in these recurrences the accelerated treatment concept, again with success. In Szczecin a thoracomyoplasty, as described by Jadczyk,¹⁴ was performed. All these patients recovered with no signs of recurrence.

The accelerated concept was applied in the majority of cases of early PPE as well. This might occasionally be an overtreatment. However, in 2 of our cases, the chest was successfully closed directly after debridement, indicating that in selected cases repeated reinterventions are not necessary. It has been shown by different authors¹⁵⁻¹⁷ that cleaning of the infected chest is possible as a 1-stage procedure done minimally invasively with the use of a video thoracoscope.

However, in patients with chronic empyema or complicated with a BPF, we and others assume that only an open approach with repeated interventions will lead to a clean chest cavity.^{1,10,18,19}

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Discussion

Dr Francis C. Nichols (Rochester, Minn). In 1915, an eventual president of this association and the Mayo Clinic's first thoracic surgeon, Samuel Robinson, wrote, and I quote, "Certain thoracic diseases, which for generations have fallen to the lot of the surgeons, are yet badly handled. Conspicuous among these is the patriarch of the surgical scrap-heap, chronic empyema." Dr Robinson then went on to say that there is obvious opportunity for improvement in the treatment of this disease, and I think that remains true today. Prevention remains the most effective method of dealing with PPE and BPF, and as we all know, among these preventative measures are avoidance of contamination of the pleural space during pneumonectomy and not leaving the bronchial stump too long while at the same point in time not devascularizing the stump and the prophylactic reinforcement of the stump in the face of what I call hostile conditions, namely radiation and certain infections. Despite these precautions, these problems continue to occur.

In our most recent series, we reviewed 84 patients with PPE over a 16-year period of time. Our mortality was 7%, and our median hospital stay was 30 days. Therefore you and your colleagues are to be commended on the results of your management. Although every death is a tragedy, the 4% mortality you report is noteworthy; with median follow-up of almost 2½ years, your ultimately successful treatment of 97% of the patients is also commendable, and because your median hospital stay is 18 days, that is enviable.

As we all know and have heard, improvements in the management of this disease have occurred, including the Clagett procedure and its modification, whereby living tissue is transposed into the thoracic space. We believe that muscles of the chest wall are ideal for transposing into the chest because all are large enough and long enough to reach most intrathoracic locations. Most frequently we choose the serratus anterior, the latissimus dorsi when it is still available, and the pectoralis major muscles. Given our success with these muscles, we have rarely used omentum because we would like to avoid opening the contaminated abdominal cavity.

I have a few questions. I would like to focus first on the BPFs. Forty-four of your patients (ie, 58%) had a BPF. You stated that if a BPF was present, you protected the contralateral lung. We believe the protection of the contralateral lung is actually paramount in all cases and use a single-lumen endotracheal tube to block off the remaining main stem bronchus or a double-lumen tube. Some of the fistulae you saw were small and might have only been detected in the operating room. Of the 44 BPFs, how many were only identified in the operating room?

Dr Schneider. Dr Nichols, thank you for your questions, and thank you for your comments.

As you expected, we use mostly a double-lumen endotracheal tube and rarely a single-lumen tube, which is positioned into the remaining main bronchus during anesthesia to protect the stump but especially the contralateral lung. All BPFs were suspected in the clinical or radiologic presentation, but 5 of them were tiny and only detected during the operation by applying air pressure to the water-submerged stump.

Dr Nichols. This leads to my next question. Focusing on the subset of BPF, 9 patients, as you put it, had pinhole insufficiency, in which merely the pinhole was sutured and protected with surrounding tissue. There were 10 patients who ultimately experienced recurrent empyema, and 6 of those 10 had BPFs found at re-exploration. How many of these 6 came from this pinhole and local tissue control group? Additionally, what do you mean by local tissue because these chests are usually very scarred and inflamed?

Dr Schneider. You are absolutely right that it is impossible to use any local tissue in late-occurring empyemas because of the explanation you just gave. In 2 of these 6 patients with recurrence of the BPF, both only a few days after definitive closure in the first attempt, a pericardial fat flap was used for covering. We used pericardial fat in another 3 patients without further complications.

Dr Nichols. You transposed omentum in 18 cases, a variety of muscle flaps in 11 cases, a pericardial fat pad in 5 cases, and an azygos vein actually in 1 case. Therefore of the 6 BPFs, how many of those actually had soft tissue coverage in the first place? I think you might have just answered part of the question, but what failed?

Dr Schneider. There was failure in 2 in which the pericardial fat flap was applied. The other 3 with the same type of coverage healed fine. Therefore we believe that in very early cases of empyema

caused by pinhole bronchial stump insufficiencies, local soft tissue can be applied as a first choice when a well-vascularized pericardial fat flap can be prepared. However, in Zurich we use the omentum as the first choice with excellent success, which is in contrast to our colleagues in Szczecin, who prefer to apply extrathoracic muscle coverage.

Dr Nichols. I am intrigued by your use of omentum. In your manuscript you failed to talk about operative morbidity. Were there any intra-abdominal complications related to the use of the omentum, peritonitis in particular?

Dr Schneider. Surprisingly, we did not observe peritonitis or any wound infection or any other abdominal complications in our patients.

Dr Nichols. In the manuscript you talk about repeatedly closing the skin. You had a median of 3 repeat pack changes, and as opposed to most of us who would just pack the chest open, you actually close the skin, I am assuming with sutures or clips, and now based on your presentation, you actually place a drain. In essence, you are sort of doing a wound VAC-type approach. Is that right?

Dr Schneider. That is right. We fill the chest with povidone-soaked dressings, one drain between the dressings and the lateral chest wall, and we adapt the ribs and close the fascia but leave the muscle layer untouched until the final closure. The skin is closed with staplers. The patient receives an elastic rib belt not only applied during mobilization but also during bed rest.

Dr Nichols. Do you maintain suction on this closure?

Dr Schneider. Yes, a constant suction of -5 to -10 cm of water is applied, which might give a VAC-type effect to the cavity.

Dr Nichols. Finally, the median hospital stay of 18 days is truly enviable. The median number of days, however, from the final closure to hospital discharge was almost 2 weeks. Why were the patients hospitalized so long after final wound closure?

Dr Schneider. Actually, in most European hospitals patients are treated in the hospital until they are well recovered without drains and able to go back home. In the North American system, I would expect that these patients would be treated ambulatory 2 to 5 days after final closure. Maybe we will do this as well for cost reasons in the future.

Dr Nichols. Again, thank you for the opportunity to discuss this paper, and I commend you on your results.

Dr Schneider. Thank you very much.

Dr Erino Rendina (Rome, Italy). Again, congratulations on an excellent paper and on an innovative approach to this problem, which all of us are obliged to face.

I have a few questions. You mentioned that several of your patients had undergone pleuropneumectomy for mesothelioma, and that implies that those patients must have had some kind of prosthesis in their chests. How did you handle this? Did you have to remove the diaphragmatic prosthesis or the pericardial prosthesis?

Dr Schneider. Actually, there were 5 patients who had pleural pneumonectomy, and in all of them, we did remove the pericardial prosthesis we put in because we saw some kind of infection area around this, but we never took out the diaphragmatic prosthesis.

Dr Rendina. Thank you. There might be a high variability of general conditions in these patients; in particular, sepsis might deteriorate the clinical conditions and put patients at risk for repeated

surgical procedures. Did you have patients who could not undergo such an aggressive approach because of their compromised general condition, fever, and sepsis? In other words, was any patient with empyema that you observed over the study period excluded from your cohort?

Dr Schneider. Actually, we operated on all patients in the same way. We did not do an alternative approach. But you are right. There have been patients in a very ill status when they came. We were a little bit surprised as well that after the first intervention, once you have taken out the infected tissue, the patient is doing better very quickly. And the second intervention is a very short one. It is just opening, changing the dressings, doing an aggressive debridement again, and repacking it with this dressing. It takes between 45 minutes and maybe an hour. Actually, we never saw a problem. We were surprised as well at the beginning that it works. Actually, we never had a problem.

Dr Rendina. Finally, I concur with you that a very small pinhole fistula can be closed right away at the first procedure. What about larger fistulae in which the wall of the bronchus is fragile and would not hold the sutures? Would you close it at the first procedure or wait for the tissue integrity to be restored and buttress the suture in a later procedure?

Dr Schneider. Actually, it depended a little bit on the size of the hole. If the hole is too big, then we can just pack it with these dressings, and we have to be afraid that maybe some of the leakage spills on the other side, and then we tried to cover it or to close it in the first attempt. If the hole was not so big, we might have done it also in the second attempt, but usually we did it in the first. And if the hole was big and we could not close it, we did directly suture the omentum on the hole. We did not close the hole. We directly put it on the hole.

Dr Rendina. Thank you. Congratulations again.

Dr Joel D. Cooper (Philadelphia, Pa). I want to congratulate the authors on what I think is a great contribution.

I first heard about this sort of thing 20-some years ago when Michael Perlman from Moscow told me that they had done 75 cases with almost universal success, and they did it with an ultrasonic generator. He said they would gradually fill the chest and add the generator until the water boiled as a form of debridement. His friends joked that he was killing the spine of the bacteria, but I am not sure that I believed him. I thought maybe something was lost in translation. However, when I visited Zurich and saw some of these patients and when I hear this presentation, I think it is a great contribution. I think that you have established or at least confirmed the fact that it is possible to take an infected chest and in virtually a single stage, notwithstanding the few trips to the operating room, shorten the whole process, when most of us, including myself, still put these patients through a Clagett window, a cleanup procedure, and a filling with tissue. I think this is a very important principle that you have confirmed. I have one minor addition. On a few cases, when there has been a small fistula, a little postage stamp of Surgicel with fibrin glue put over the fistula and then reinforced with fibrin glue and then omentum or muscle over it and then a packing gives a very good closure without air blowing up the flap. I have never done it the way you have. I have always done it staged. But I think it is a great contribution, and my congratulations to you on a good presentation.

Dr Schneider. Thank you very much, Professor Cooper.