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# Lung Sealing with the Sandwich-Technique: A New Surgical Method to Deal with the Emphysematous Lung

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**Rezumat**

***Tehnica "Sandwich": o nouă metodă de sutură a suprafeței pulmonare în caz de emfizem pulmonar***

Pierderile aeriene postoperatorii persistente sunt o complicație frecventă şi deseori dificil de tratat după rezecții pulmonare. Îndeosebi în caz de emfizem pulmonar, închiderea spontană a suprafeței pulmonare prin tratament conservator (tub de dren) poate fi foarte întarziată sau chiar imposibilă, iar o reintervenție operatorie pentru sutura pulmonară este uneori inevitabilă. O soluție ideală în astfel de cazuri nu este încă cunoscută, toate tehnicile având avantaje dar şi limite, o reintervenție operatorie reprezentând pentru aceşti pacienți tarați un risc suplimentar semnificativ. În această lucrare, o metodă nouă de suturare a suprafeței pulmonare este prezentată şi exemplificată prin două cazuri clinice. Pe scurt, două benzi de TachoSil® sunt aplicate pe pleura viscerală de ambele părți ale leziunii pulmonare. Închiderea leziunii se face prin suturi cu fire întrerupte trecute prin benzile de TachoSil®. Sutura va fi în final acoperită de un al doilea burete de TachoSil® care însă depăşeşte în toate direcțiile primului strat ("Sandwich-Technique"). În experiența noastră, deşi limitată, această tehnică s-a arătat eficientă în prevenirea sau tratarea fistulelor pleuro-pulmonare persistente şi a fost folosită în special la pacienți cu emfizem pulmonar în situații în care alte metode păreau sortite eşecului.

**Cuvinte cheie:** emfizem pulmonar, fistulă pleuro-pulmonară persistentă, adeziv tisular

**Abstract**

The persistent air leak is a common and sometimes difficult to manage complication after major pulmonary resections. Especially in cases with lung emphysema spontaneous sealing of the lung surface under conservative therapy can be prolonged or even fail and a reoperation to close the damaged visceral pleura might be necessary. An ideal surgical solution to deal with this problem is not known, all of the techniques have advantages but also limitations and additional operations should be avoided in this group of frail patients. In this paper a new surgical method to seal the lung surface is presented based on two exemplary cases and our clinical experience. Basically, two stripes of fleece bounded fibrin based sealant are put on the visceral pleura parallel to the wound, which will be then closed by multiple stitches of absorbable suture line inserted through the stripes. Afterwards, a second layer of the same sealant will be placed over it to cover the suture with a narrow overlapping in all directions to the adjacent visceral pleura ("Sandwich-Technique"). In our experience, this technique can be used to successfully prevent or treat persistent air leaks especially in patients with lung emphysema in whom otherwise treatment options are limited.

*Abbreviations:* VATS = video-assisted thoracoscopic surgery POD = postoperative day LVRS = lung volume reduction surgery FEV1 = forced expiratory volume in the first second DLCO = diffusing capacity of the lung for carbon monoxide

**Key words:** lung emphysema, persistent air leak, fleece bounded sealant

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## Introduction

Intraoperative air leaks following lung resections are frequent and estimated to occur in 50-70% of these operations [1, 2]. Postoperative air leaks continue to be the most common adverse finding after pulmonary resections and as much as 5% of air leaks are the only remaining factor for prolonged hospital treatment [3]. Air leaks persisting for more than 7 days after primary surgery are considered to be a complication. They contribute to a significant prolongation of hospital stay and increase the risk for postoperative empyema. [4, 76 5]. This period of one week, however, is arbitrary and seems to be inappropriate in the age of fast-track and minimally invasive surgery [6, 7]. The reported incidence of air leaks after open lung resections ranges between 15 - 25% and can be as high as 50% after lung volume reduction surgery (LVRS), but even after small minimally invasive procedures as the pneumothorax therapy air leaks can be seen in as much as 6% of the cases [5, 8-10]. On the other hand the Video-assisted thoracoscopic surgery (VATS)-Lobectomy seems to reduce the risk for this complication (about 5% in the largest series) especially if the "fissure last" technique was used [11-13].

The full reexpansion of the lung and apposition of the two pleural surfaces is the most important premise to obliterate the air leaks. Still, a large number of other factors are predisposing for this complication: lung emphysema, systemic steroids prior to surgery, dens adhesions, upper lobectomy or bilobectomy and redo surgery. Therefore, techniques have been developed to prevent postoperative air leaks, such as reducing the residual pleural space by creating a pleural tent or pneumoperitoneum or the use of buttressed staple line [3, 14, 15]. Several sealants were analysed in a prospective randomized manner but the actual data do not support the routine use of any of these in pulmonary surgery. The largest published series analyses the use of TachoSil®, which seems to be beneficial in preventing air leaks after primary and redo lung surgery [7, 16].

In most of the cases, by conversion from suction to water seal on postoperative day 2 a cessation of the air leaks was encountered in 59% within 12 hours and in additional 14% by the morning of postoperative day 3 in one series of 101 patients with lung surgery published by Cerfolio et al [17]. In five out of these patients a persistent air leak over seven days occurred and stopped in all cases without further complications after talc slurry. In a consecutive publication of the same author the Heimlich valve was used in an outpatient setting. Most of the air leaks sealed within two weeks without major complications. After this time the chest tube can be removed regardless of the intensity of the air leak or presence of pneumothorax [3]. Nevertheless, patients experience significant discomfort and are at higher risk to develop empyema, wound infection and pneumonia [1, 7]. Other methods to seal postoperative air leaks are the application of autologous blood, fibrin or talcum over the drainage in the attempt to induce pleurodesis.

The need for reoperation to close the lung surface and perform pleurodesis is rare and reserved for the difficult cases, in which the conservative therapy fails: progressive air leak or pneumothorax, worsening subcutaneous or mediastinal emphysema and respiratory failure due to a severe air leak. In these situations, the conservative therapy is strongly limited and the reoperation can dramatically improve and shorten the course of the patient.

## Material and Methods

For the purpose of this publication we retrospectively reviewed all the cases with atypical or anatomical lung resection other than pneumectomy operated in our institution during 2013, regardless of the underling pathology and operating technique (open vs. VATS). Patients with lung resections performed during surgery for empyema or mesothelioma as well as patients receiving lung volume reduction surgery were excluded. Cases with persistent air leak (more than 7 days after primary surgery) were identified and analysed regarding procedure used to seal the leak, hospital stay and further complications. To rule out eventual late complications a minimum follow-up of 3 weeks after discharge was warranted in all cases with persistent air leak.

### *Surgical technique*

After reopening or performing an antero-lateral thoracotomy the lung will be liberated from adhesions, blood or fibrin masses. Then, the lung will be put under water and inflated to localise the air leaks. In a deflated state the opening in the lung surface will be explored and eventually necrosis or blood residues will be removed. Perforation sites are sometimes seen near to mechanical suture lines where intrapulmonary hematomas with secondary parenchymal necrosis can occur. On both sides of the defect two approximately 1 cm wide stripes of fleece bounded fibrin glue (TachoSil®) will be put on

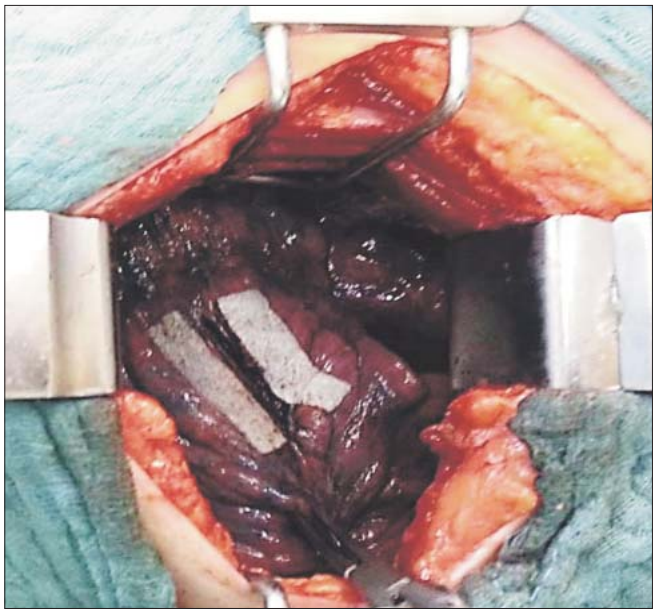

***Figure 1.*** *Two 1 cm stripes of TachoSil® fixed on both sides of the lung wound*

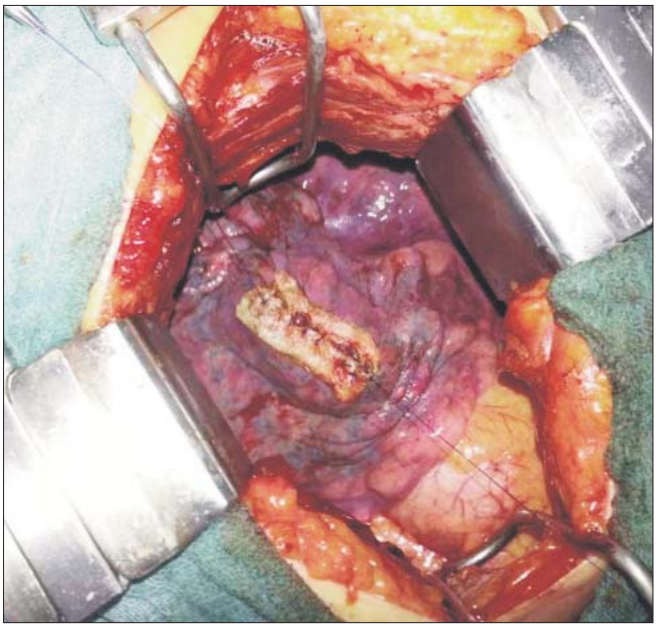

***Figure 2.*** *Terminated suture line of interrupted monofile material through the fleece stripes*

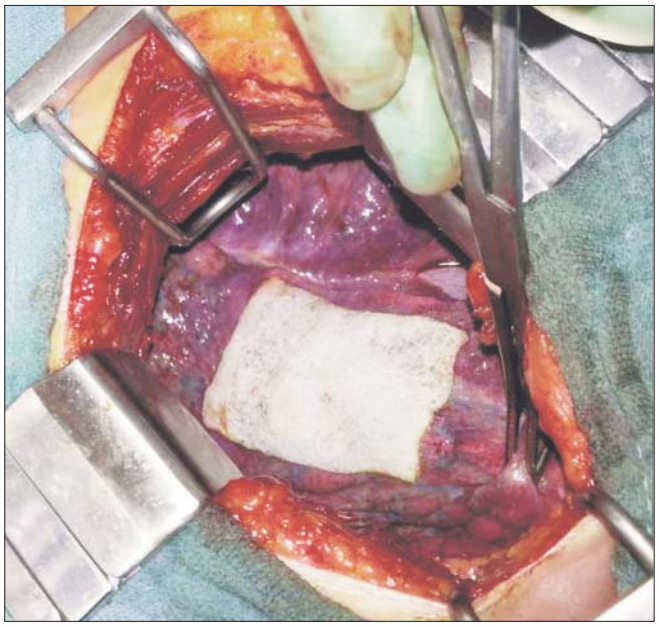

***Figure 3.*** *Entire construct covered overlapping with a TachoSil® fleece*

the visceral pleura just adjacent to the defect margins (*Fig. 1*). Care should be taken that the length of the strips at both ends exceeds that of the defect about a few millimetres. The wound will be then closed by interrupted sutures of 4-0 or 5-0 absorbable monofilament material (*Fig. 2*). The suture should be placed approximately in the middle of the strips and grasp deep in the lung parenchyma. Non-interrupted sutures should be avoided because of the risk to tear the visceral pleura by putting the line under tension. A second sheet of TachoSil® which exceeds the first level of the construct by approximately 5 mm in all directions will be placed on top (*Fig. 3*). The suture lines have to be cut close to the knot so that none of them exceed the margins of the overlaying fleece. An underwater test of the airtightness up to 25 cm H2O ventilation pressure will confirm the absence of an air leak. Additionally, a pleurodesis manoeuvre such as partial parietal pleurectomy or pleural abrasion can be performed.

In our experience, during the last year a total of 123 lung resections (64 anatomical resections other than pneumectomy and 59 atypical resections including multiple resections for lung metastasis) were performed at our institution with an incidence for persistent air leak of 12% (n=15). In 12 cases the complication was encountered after a major pulmonary resection other than pneumectomy (incidence of 19% persistent air leak in this group) and in three cases after an atypical resection. The treatment was conservative (prolonged chest drainage between postoperative day (POD) 8 and 17, median 10 days) in nine cases (60%) with additionally use of blood pleurodesis in one case. In this group, one empyema occurred 3 days after removal of the chest drainage (12 days of conservative therapy for air leak) and necessitated rethoracotomy for decortication.

A reoperation to seal the lung was performed in six cases (40%) and has each time lead to cessation of the air leak with immediate removal of the chest tubes and without further complications. *Table 1* shows the history, cause of air leak, presumable risk factors and the used sealing method for the reoperated cases. The Sandwich-Technique was used therapeutically only in three cases, all with severe lung empysema.

In four further cases (one deep enucleation for benign tumor, two bulla resections for symptomatic pneumothorax and one LVRS) the Sandwich-Technique was used prophylactic due to severe lung emphysema and insufficiency of the suture line. In all of these patients a postoperative air leak was not encountered.

Our algorithm to manage persistent air leaks after lung resections is in the first line conservative. In case of fully expanded lung and chest drainage lying presumably in the area of the air leak an autologous blood pleurodesis with 100-125 ml blood will be performed on POD 5 to 7 as described by Shackcloth et al [18]. When a residual pneumothorax is encountered or the blood pleurodesis remains without result, a reduction of the suction pressure or even water seal will be used to facilitate the healing process of the lung surface. On POD 10 to 14 the drainage will be clamped for 24 hours. If the chest X-ray shows stable findings in terms of lung expansion and subcutaneous emphysema the chest tube can be removed regardless of the air leak, otherwise the operative lung sealing will be considered. The most frequent indication to reoperation remains a persistent strong or progressive air leak, an increasing pneumothorax and/or subcutaneous emphysema despite adequate pleural drainage. In these cases a preoperative bronchoscopy should be performed to exclude a bronchial stump insufficiency.

To better understand our strategy two cases are described.

*Case 1:* A 58-year-old male patient with apically predomi-

***Table 1.*** *Gender/age History Air leak cause Risk factor Sealing technique*

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| Male/72y | - Atypical resection of two lung metastases | Rupture of the suture line | Postoperative mechanical ventilation with severe barotrauma | Lung suture covered with TachoSil® |
| Female/67y | - Upper bilobectomy<br>- Unsuccessful blood pleurodesis<br>- Reoperation on POD 8 | Lung necrosis near mechanical suture line | Neo-adjuvant chemotherapy | Lung suture covered with TachoSil® |
| Male/70y | - Upper lobe resection<br>- Unsuccessful blood pleurodesis<br>- Reoperation on POD 10 | Ruptured emphysem bulla | Severe lung emphysema | Sandwich Technique |
| Male/42y | - Bulla resection<br>- Reoperation on POD 7 | Perforated emphysem bulla | Severe lung emphysema | Sandwich Technique |
| Female/67y | - Lower lobe resection<br>- Reoperation on POD 12 | Interlobar preparation area | Neo-adjuvant chemotherapy | TachoSil® only |
| Male/58y | - Upper lobe resection<br>- Reoperation on POD 2 | Ruptured emphysem bulla | Severe lung emphysema | Sandwich Technique |

nant heterogeneous emphysema (forced expiratory volume in the first second (FEV1) 43% x Pred., diffusing capacity of the lung for carbon monoxide (DLCO) 45% x Pred. was uneventful operated for lung cancer (VATS lobectomy of the right upper lobe). On POD 2, despite initial air tightness a rapidly progressive air leak with subcutaneous emphysema, progressive dyspnea and small hemoptysis forced us to immediately reoperate. For a better exposure we chose to perform an antero-lateral thoracotomy. An irregular laceration of the visceral pleura of a large bulla in segment six with an underlying hematoma was the cause of this strong air leak. Because of the central extension of the bulla and the fragile visceral pleura we decide not to perform an atypical resection of the lesion, instead we closed the leak with the Sandwich-Technique after removing the underlying hematoma. A partial parietal pleurectomy of the apical region was added. After the revision no further air leaks war encountered.

*Case 2:* A 60-year-old female patient with diffuse lung emphysema was explored over an antero-lateral thoracotomy for a centrally located 1,5 cm nodule in the left upper lobe. The previously performed CT-guided puncture of the lung was complicated with pneumothorax without positive histologic result. Due to a pulmonary sarcoidosis the patient also received 15 mg prednisolon / day. The intraoperative finding suggested a hamartoma which was enucleated. The lung parenchyma was adapted in layers with multiple stitches of resorbable monofile 4-0 line. The under water probe reveals a significant air leak. Therefore, the suture line on the lung surface was reopened and finally closed with the Sandwich-Technique (*Fig. 1 to 3*). In this case the method was used in a prophylactic approach, further intra- or postoperative air leaks were not encountered.

## Discussion

The Sandwich-Technique used to seal defects of the visceral pleura is a new method to deal with difficult situations of persistent air leak especially in patients with lung emphysema. In selected cases with high risk for developing this complication the technique can be also used in a prophylactic manner. In our experience, an antero-lateral thoracotomy was performed in each case, because of the better exposure and to warrant an adequate submersion test to localise every possible air leak.

The effectiveness of this method is presumably due to the combination of the strength of the suture line with the sealing properties of TachoSil® and the reduction of the tension in the suture by distributing it on a greater surface. By reinforcing the suture line with two fleece stripes the fragile visceral pleura will be protected from tearing. The second layer of adherent fleece gives more strength to the surface, it additionally seals the stitches and distributes the tension on the visceral pleura more equally. Another potential benefit is that further resection of the lung, which may otherwise increase the unobliterated pleural space, is no longer necessary.

The limitations of the method in the therapeutic setting are the need for reoperation and for optimal exposure which can be mostly achieved by thoracotomy only. Therefore, careful patient selection is mandatory. For the prophylactic use, the detriments emerge from the higher costs due to sometimes greater amount of fleece bounded sealant to be used and the additional operating time needed to perform the Sandwich-Technique.

Our positive experience with this new technique encouraged us to integrate this approach in our algorithm for the management of air leaks after pulmonary resections. In addition, further research is planned to objectively analyse the effectiveness and costs of this technique and to compare it with other sealing methods of the lung.

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