Management of Spontaneous Pneumothorax and Postinterventional Pneumothorax: German S3-Guideline*

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Schlüsselwörter

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Bibliography

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ABSTRACT

In Germany, 10,000 cases of spontaneous pneumothorax are treated inpatient every year. The German Society for Thoracic Surgery (DGT), in co-operation with the German Society for Pulmonology (DGP), the German Radiological Society (DRG) and the German Society of Internal Medicine (DGIM) has developed an S3 guideline on spontaneous pneumothorax and postinterventional pneumothorax moderated by the German Association of Scientific Medical Societies (AWMF).

Method Based on the source guideline of the British Thoracic Society (BTS2010) for spontaneous pneumothorax, a literature search on spontaneous pneumothorax was carried out from 2008 onwards, for post-interventional pneumothorax from 1960 onwards. Evidence levels according to the Oxford Center for Evidence-Based Medicine (2011) were assigned to the relevant studies found. Recommendations according to GRADE (A: "we recommend"/"we do not recommend", B: "we suggest"/"we do not suggest") were determined in three consensus conferences by the nominal group process.

Results The algorithms for primary and secondary pneumothorax differ in the indication for CT scan as well as in the indication for chest drainage application and video-assisted thoracic surgery (VATS). Indication for surgery is recommended individually taking into account the risk of recurrence, life circumstances, patient preferences and procedure risks. For some forms of secondary pneumothorax, a reserved indication for surgery is recommended. Therapy of postinterventional spontaneous pneumothorax is similar to that of primary spontaneous pneumothorax.

Discussion The recommendations of the S3 Guideline provide assistance in managing spontaneous pneumothorax and post-interventional pneumothorax. Whether this will affect existing deviant diagnostic and therapeutic measures will be demonstrated by future epidemiological studies.

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ZUSAMMENFASSUNG

In Deutschland werden jedes Jahr 10.000 Fälle von Spontanpneumothorax stationär behandelt. Die Deutsche Gesellschaft für Thoraxchirurgie (DGT) hat in Kooperation mit der Deutschen Gesellschaft für Pneumologie und Schlafmedizin (DGP), der deutschen Röntgengesellschaft (DRG) und der Deutschen Gesellschaft für Innere Medizin (DGIM) in Moderation mit der Arbeitsgemeinschaft der wissenschaftlichen medizinischen Fachgesellschaften (AWMF) eine S3 Leitlinie zum Spontanpneumothorax und postinterventionellen Pneumothorax entwickelt.

Methode Ausgehend von der Quellleitlinie der Britisch Thoracic Society (BTS) zum Spontanpneumothorax von 2010 wurde eine Literaturrecherche zum Spontanpneumothorax ab 2008, zum postinterventionellen Pneumothorax ab 1960 durchgeführt. Den relevanten gefundenen Studien wurden Evidenzlevel nach dem Oxford Centre for Evidence-Based Medicine (2011) zugeteilt. Die Empfehlungen wurden in 3 Konsensuskonferenzen nach GRADE (A: „wir empfehlen"/„wir empfehlen nicht", B: „wir schlagen vor"/„wir schlagen nicht vor") im nominalen Gruppenprozess konsentiert.

Ergebnisse Die Algorithmen zum primären und sekundären Pneumothorax unterscheiden sich in der Indikation zur CT-Thorax sowie in der Indikationsstellung zur Drainagenanlage und minimalinvasiven Operation. Die Operation wird individuell empfohlen unter Berücksichtigung von Rezidivrisiko, Lebensumständen, Patientenpräferenzen und Prozedurenrisiko. Bei einigen Formen des sekundären Pneumothorax wird eine zurückhaltende Indikationsstellung zur Operation empfohlen. Die Therapie des postinterventionellem Spontanpneumothorax ähnelt dem des primären Spontanpneumothorax.

Diskussion Die Empfehlungen der S3-Leitlinie bieten Hilfestellungen im Management des Spontanpneumothorax und des postinterventionellen Pneumothorax. Ob diese auf derzeitig teilweise bestehende abweichende diagnostische und therapeutische Maßnahmen Einfluss haben, werden künftige epidemiologische Studien zeigen.

Introduction

Spontaneous pneumothorax is a widespread clinical entity with about 10 000 events per year in Germany. The afflicted patients are treated in various sectors of medicine by a wide spectrum of specialists. For this reason, the German Society of Thoracic Surgery, the German Society of Pneumology and Respiratory Medicine, the German Society of Internal Medicine and the German Roentgen Society are presenting an evidence-based guideline to provide scientifically-based and pragmatic treatment instructions for all doctors who are confronted with the diagnostics and therapy of pneumothorax. Since pneumothorax may also occur postinterventionally in various areas of medicine and is subject to comparable treatment strategies, this has also been included in the guideline. Thus, the present guideline encompasses the following forms of pneumothorax for adult patients:

- Primary Spontaneous Pneumothorax
- Secondary Spontaneous Pneumothorax
- Postinterventional Pneumothorax

Pneumothorax in children, postoperative pneumothorax, traumatic pneumothorax or pneumothorax under respiration are not covered by this Guideline.

Methods in Creating the Guideline

The current S3-guideline was developed using the evidence-based guideline of the British Thoracic Society (BTS) for the Management of Spontaneous Pneumothorax dated 2010 [1] as a source guideline. The references cited there and the literature found in our own systematic research starting in 2008 (for postinterventional pneumothorax starting in 1960, since it was not a topic in the source guideline) formed the basis for 37 recommendations, respectively 8 statements. 14 recommendations were adopted in a consensus of experts due to a lack of studies. The guideline report makes clear which recommendations were adopted without change from the source guideline after examination and which could be adopted with modifications. The guideline group decided in the first Consensus Conference to grade the recommendations not according to the three-step formulation scheme of the AWMF, which has been most commonly used thus far (A: "should/should not", B; "ought to/ought not to", 0: "can/cannot") but according to the more current formulation by grade (A: "we recommend/we do not recommend", B: "we suggest/we do not suggest").

The evidence grade of the recommendations was determined as cited by the Oxford Centre for Evidence-Based Medicine (Schema 2011) with grade 1 – grade 5. In case of missing evidence, the recommendations were assessed in the consensus of experts (EC).

The recommendations were discussed in 3 Consensus Conferences and the guideline definitively adopted in a Delphi Procedure.

The methodical processes in creating the S3-guideline are presented in full in the guideline report.

1 History, Definition, Etiology, Epidemiology, Anamnesis, Findings, After-care of Pneumothorax

The term "Pneumothorax" was first coined by Itard in 1803, later characterized by Laennec in 1819 and denotes the collection of air in the pleural cavity [2]. At that time, most cases of pneumothorax were attributed to tuberculosis, even though pneumothoraxes were seen in otherwise healthy patients ("simple pneumothorax"). The first description of pneumothorax in otherwise healthy patients (primary spontaneous pneumothorax, PSP) was published by Kjaergaard in 1932 [3].

1.1 Definition and Aetiology of Pneumothorax

The clinical division into primary and secondary spontaneous pneumothorax (PSP and SSP) is of decisive importance for the diagnostics and therapy of the patient. For this reason, care should be taken to reach as unequivocal a definition of the clinical picture as possible during the primary examination of the patient.

The patient's anamnesis must be completely recorded with respect to lung diseases. In addition, concrete questions should be asked concerning pulmonary symptoms prior to the pneumothorax event. The structure of the unaffected lung in an overview X-ray must be considered to avoid overlooking signs of a secondary pneumothorax.

1.1.1 Primary Spontaneous Pneumothorax (PSP)

Primary spontaneous pneumothorax denotes a suddenly-occurring pneumothorax without previous thorax intervention or injury in patients less than 45 years of age without pre-existing pulmonary disease, with an unremarkable contralateral lung in the overview X-ray. In these patients, defined as lung-healthy, pathological findings in the lung may still be identified. Thus, up to 90% of the patients present with subpleural vesicles and bullae [4, 5]. These findings have thus been ascribed a role in the onset of pneumothorax. Several autofluorescence studies [6] showed pleural porosities in the surrounding pleural region which were not visible with white light.

1.1.2 Secondary Spontaneous Pneumothorax (SSP)

S1	Statement	2017
Statement	Secondary Spontaneous Pneumothorax is associated with higher morbidity and mortality than Primary Spontaneous Pneumothorax.	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Tanaka 1993 [7], Norris 1968 [8], Mathur [9] de Novo Research: Brown 2014 [10]	
	Consensus rate: 100%	

If the patient suffered lung disease previously, if pulmonary symptoms existed prior to the onset of pneumothorax, if a pathological lung structure is observed in the X-ray image on the non-affected side, or if the patient is 45 or older and smokes, a secondary spontaneous pneumothorax can be assumed. The morbidity and mortality of pneumothorax in patients with pre-existing lung disease are higher than in PSP and dependent on the degree of pre-existing lung damage. Treatment is more difficult, not only because of age-related concurrent diseases, expressed for example in longer hospitalization and higher mortality [9, 11, 12]. The significantly increasing rate of mortality and the concurrent diseases in spontaneous pneumothorax at age 45 or older are associated with an increase in SSP compared to PSP in patients older than 45 (see ▸ **Fig. 2**).

▸ **Table 1** Characteristics of primary and secondary pneumothorax (according to Bobbio [11]).

	Primary Spontaneous Pneumothorax (PSP)	Secondary Spontaneous Pneumothorax (SSP)
Proportion of all spontaneous PTX (%)	85	15
Patient age (yrs)	35 ± 18	53 ± 20
Sex (m : f)	76 : 24	80 : 20
Underlying lung disease	No	Yes
Clinical picture	Often complaint-free	Depending on severity of the underlying lung disease
Concurrent diseases	rare	frequent

▸ **Table 2** Lung diseases which may lead to secondary pneumothoraxes [13].

Obstructive lung diseases	COPD/Emphysema [7, 14–16]
	Cystic Fibrosis [17]
	Severe asthma [18]
Infections	Pneumocystis jiroveci Pneumonia [19, 20]
	Tuberculosis [7, 21]
	Non-tuberculous mycobacteriosis [22]
	abscessing pneumonia
Interstitial lung diseases	Fibrosing lung diseases [7, 15, 16]
	Cystic lung diseases: ▪ Langerhans cell Granulomatosis [23] ▪ Lymphangioleiomyomatosis (LAM) [24] ▪ Birt-Hogg-Dubé-Syndrome [25, 26]
	Sarcoidosis [27]
Malignant diseases	Lung carcinoma [7, 28]
	Secondary malignant neoplasia of the lung [29]

1.1.3 Iatrogenic Pneumothorax

In medical interventions, such as acupuncture, orthopaedic injection, CT-guided lung biopsy, bronchoscopy lung biopsy, application of a central venous catheter or thoracentesis may result in injury to the visceral pleura with leakage of respiratory air in the pleural space.

1.1.4 Traumatic Pneumothorax

Penetrating or blunt thorax traumata lead to uni- or bilateral pneumothorax via injury to the lung parenchyma, the tracheobronchial tree or defects in the thoracic wall.

1.1.5 Catamenial Pneumothorax

In this rare clinical picture, young women suffer spontaneous pneumothorax within 72 hours before or after menstruation, usually on the right side. Typical symptoms are thoracic pain, dyspnoea and haemoptysis [30]. There is a high tendency to recurrence as well as a temporal relationship to the menstrual cycle. The pathogenesis has not been definitively clarified [31, 32]: There is evidence for endometriosis as the cause of this rare form of pneumothorax; alternatively, the aspiration of air via the uterus and Fallopian tube intraabdominal and from there via fenestrations in the diaphragm into the pleural space is discussed.

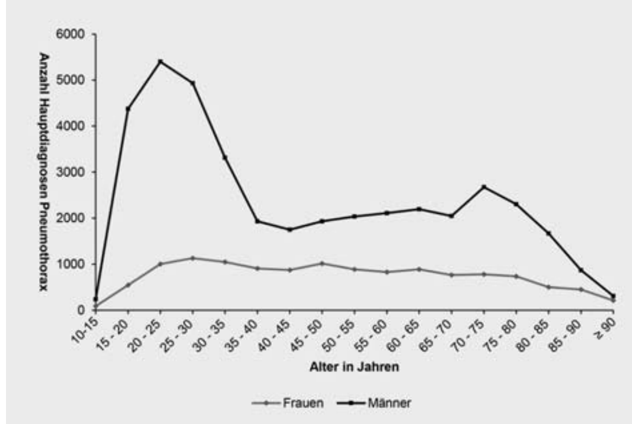
1.1.6 Pneumothorax During Pregnancy

In principle, women have a lower risk than men of developing a spontaneous pneumothorax. However, pregnancy and the birth process appear to increase the individual risk [33].

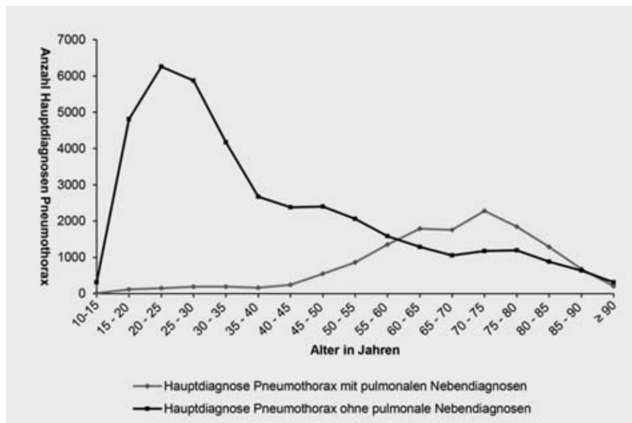
1.2 Epidemiology

1.2.1 Incidence

Pneumothorax is a relevant global health problem. A current study from France covering the period 2008 to 2011 [11] shows a pneumothorax incidence in inhabitants older than 14 years of age of 22 cases per 100 000 inhabitants, whereby men are more frequently affected than women by a factor 3.3. According to data from the Federal Bureau of Statistics (Statistischen Bundesamtes) [12] for the period 2011 to 2015, there were 10 500 hospitalizations per year in Germany with the diagnosis pneumothorax. No differentiation was made between first event and recurrence. Hospitalization due to pneumothorax per 100 000 inhabitants was 22.2 for men compared to 6.7 for women. The incidence of hospitalization due to pneumothorax in men peaked at 25 years of age. Thereafter, there was a steep decrease to the age of 40, followed by a slow increase in incidence to a second peak around age 75. The second peak marked the maximum of SSP cases in the age distribution. For women, the incidence reached the maximum at age 30, but it was much lower than in young men. Then the curve decreased continuously to old age. The number of pneumothoraxes with underlying lung diseases in this study showed an increase starting at age 45 and exceeds the number of PSP starting at age 60 (▸ **Figs. 1** and **2**).



▸ **Fig. 1** Hospitalized cases with spontaneous pneumothorax (ICD J93) in Germany 2011–2015, by age and sex. Data from the Federal Bureau of Statistics [12].



▸ **Fig. 2** Age distribution of cases treated in hospital with main diagnosis spontaneous pneumothorax with and without additional pulmonary diagnoses [lung cancer (C34), pneumonia (J18), COPD (J44), interstitial lung diseases (J84)] in Germany 2011–2015. Data from the Federal Bureau of Statistics [12].

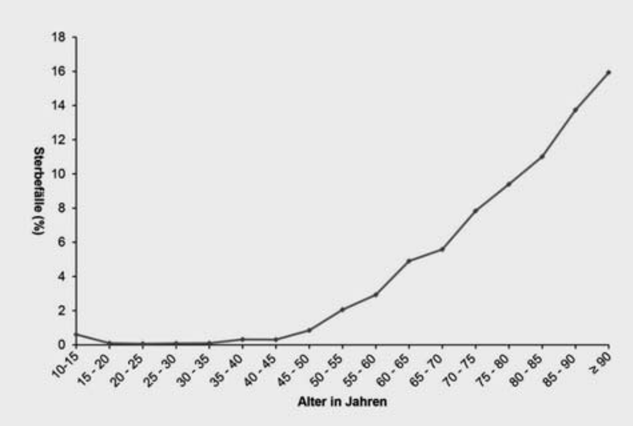
1.2.2 Recurrence Rate

Studies on the recurrence of spontaneous pneumothorax are heterogeneous; the rate in the first year is between 5 and 49%, most studies cite 20–30% (see also Chapter 3.6.1, Tabs.▸ **3** and **4**). An epidemiological study in France (Bobbio [11]) showed a recurrence rate in the first year of 26.5% in a total number of 32 618 patients under various forms of therapy. In 2014, Brown retrospectively found a recurrence of 5% in the first year in pneumothoraxes treated conservatively without drainage/puncture, and 17% under drainage [10]. In a prospective randomized study, Noppen [34] observed a recurrence rate of 26% one year after aspiration, and a recurrence rate of 27.3% after drainage therapy in the same time period.

A recent Danish prospective cohort study [35] showed a recurrence rate in PSP of 54% after drainage therapy, the median observation time here was 3.6 years.

A prospective randomized study by Chen [36] showed a recurrence rate in PSP after one year of 29.2% vs. 49.1% after aspiration and drainage with vs. without pleurodesis with Minocycline. The success rates (following removal of the drainage within 24 h) after one week were only 86.8% vs. 81.5%, so that these cases should be considered therapy failures rather than recurrences.

In a retrospective study by Lippert [37], the recurrence rate 5 years after drainage therapy of secondary spontaneous pneumothorax was higher at 44% compared to PSP at 25%. In a second study by Brown [10] after one year the recurrence rate was not significantly higher at 13% in SSP compared to PSP.



▶ **Fig. 3** Percentage of deaths in the number of hospitalized cases with the main diagnosis spontaneous pneumothorax 2011–2015 in Germany, differentiated by age. Data from the Federal Bureau of Statistics [12].

1.2.3 Mortality

Mortality during hospitalization with the main diagnosis pneumothorax up to age 45 is extremely low (▶ **Fig. 3**), as seen in current data from the Federal Bureau of Statistics [12]. A clear increase of in-hospital mortality starting at age 45 can be recognized. This increases up to 16% in patients older than 90 (▶ **Fig. 2**). In the cause of death statistics from the same source [12], there is a higher mortality in spontaneous pneumothorax for patients older than 45 with 1.3% compared to 0.03% for patients under age 45. The number of pulmonary concurrent diagnoses also increased markedly after age 45. For the Guideline Group, this was the basis for fundamental differentiation of the diagnosis in primary and secondary spontaneous pneumothorax in dependence on age (▶ **Fig. 2**). A retrospective study by Tanaka 1993 [7] was able to prove an elevated morbidity and mortality in SSP compared to PSP.

1.3 Clinical Presentation

1.3.1 Symptoms

S2	Statement	2017
Statement	Symptoms may be minimal or absent in primary spontaneous pneumothorax. Contrary to this, symptoms of secondary spontaneous pneumothorax are more pronounced, even when the pneumothorax appears relative small in imaging.	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Miller 2008 [38], O'Hara 1978 [39], Wait 1992 [40], Tanaka 1993 [7], Vail 1960 [41], Seremetis 1970 [42]	
	Consensus rate: 93%	

Typical symptoms of pneumothorax are thoracic pain and dyspnoea. The symptoms may be mild or even absent [38], so that the diagnosis pneumothorax should always be included in differential diagnostics. Many patients, especially those with primary spontaneous pneumothorax, often consult the doctor days after the first symptoms appeared when complaints are mild [39]. In general, the clinical symptoms of SSP are more serious than those associated with PSP. Most patients with SSP suffer shortness of breath independent of the extent of pneumothorax [7,40]. The symptoms are thus not reliable indicators of the extent of pneumothorax [41,42]. The symptom dyspnea is more decisive than pain symptoms for the specific treatment recommendations (e.g. drainage). Tension pneumothorax must be considered in serious dyspnea, accompanied by shock symptoms or jugular vein congestion.

E1	Recommendation	2017
Recommendation level A	Tension pneumothorax is a life-threatening emergency and must be treated without delay.	
Evidence grade 4	Literature: Guideline adaptation BTS2010: Leigh-Smith 2005 [43].	
	Consensus rate: 100%	

Tension pneumothorax in a spontaneously-breathing patient is rare. Overpressure arises in the affected pleural space by a valve mechanism in the Pleura visceralis. As a result, venous backflow to the heart is compromised. Mediastinal shift results additionally in compression of the healthy lung on the opposite side. Clinical signs are upper inflow congestion, progredient dyspnoea and hypotension. Immediate drainage of the affected pleural space is necessary to treat this life-threatening situation [43]. Considerably more frequent than the acute symptoms cited, there may be radiological signs of tension such as a depressed diaphragm on the affected side, mediastinal shift on the healthy side and expansion of the intercostal spaces on the affected side.

PSP may rarely also present as spontaneous hematopneumothorax. Bleeding in the pleural space may occur due to tearing of pleural adhesions as part of pneumothorax. The incidence is cited as up to 5% [44]. Clinically, the patients are conspicuous because of vasoconstriction (pallor) with tachycardia and drop in blood pressure.

1.3.2 Clinical Examination

The most essential sign in clinical examination is the diminution of breath sounds on the affected side in auscultation. Other symptoms may be hypersonorous percussion on the affected side and pulse-synchronous click in auscultation [38]. Soft-tissue emphysema occurs rarely. Basal muting in percussion indicates a hematopneumothorax. Tachycardia, tachypnoea and hypotension may be signs of spontaneous hematopneumothorax or tension pneumothorax.

1.3.3 Apparatus tests

The arterial blood gases are frequently pathological in patients with pneumothorax. Arterial oxygen partial pressure is reduced in 75% of the patients [8]. When the oxygen saturation in ambient air is above 92%, no arterial or capillary blood gas analysis is necessary in PSP. The extent of hypoxemia is greater in SSP than in PSP [8, 10], moreover, there is a risk of hypercapnia in COPD patients, so that blood gas analyses in SSP should be considered accordingly as clinically appropriate. Lung function examinations are not indicated in suspected pneumothorax.

The diagnosis pneumothorax is validated by imaging procedures (see Chapter 2, imaging diagnostics).

1.4 Promoting Factors for the Development of Pneumothorax

1.4.1 Smoking

S3	Statement	2017
Statement	Smoking increases the probability of developing pneumothorax in both lung-healthy patients and patients with lung disease.	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Bense 1987 [45]. de Novo Research: Cheng 2009 [46], Hobbs 2014 [47]	
	Consensus rate: 100 %	

Smoking increases the probability of developing pneumothorax. The risk, in relation to age, is elevated in healthy smoking men at 12 % compared to 0.1 % in non-smokers [45]. Histologically, Cheng [46] could demonstrate bronchiolitis in the lung tissue of PSP patients who smoked, which occurred in only 49 % of non-smoking patients with PSP. Smoking in patients with pre-existing COPD increases the risk of SSP [47].

1.4.2 Stature and Posture

Patients with primary spontaneous pneumothorax tend to be taller and to have grown more quickly than their healthy age peers [48]. A greater elastic tension in the lung tissue in the apex of these patients may explain the greater tendency to PSP [49]. In upright posture, there is a higher pressure gradient in the pleura between the base of the lung and the apex, which promotes the onset of PSP in these patients [50].

1.4.3 Physical Activity and Sports

S4	Statement	2017
Statement	The development of pneumothorax is not correlated with physical exertion.	
Evidence grade 3	Literature: Guideline adaptation BTS2010: Bense 1987 [51]	
	Consensus rate: 100 %	

There is no evidence of a relationship between the development of pneumothorax and physical exertion [51]. In physical activity such as lifting heavy loads or press breathing, the intrathoracic pressure increases. However, this distributes equally over the entire lung and the pleural cavity. Thus, the intrapleural pressure gradient is not altered.

1.4.4 Flying, Mountain Climbing, Stays at High Altitudes

S5	Statement	2017
Statement	Flying does not result in more pneumothorax events in patients with pre-existing lung diseases than in lung-healthy passengers.	
Evidence grade 4	Literature: de Novo Research: Taveira-DaSilva 2009 [52], Hu 2014 [53]	
	Consensus rate: 100 %	

Flying and stays at high altitudes expose the human body to lower air pressure than a stay at sea level. Studies have shown, however, that this does not result in an increased rate of spontaneous pneumothoraxes [52, 53].

1.4.5 Climatic Effects and Weather

There is no correlation between climatic effects, season or weather and the development of spontaneous pneumothorax [11, 54, 55].

1.4.6 Emotional Stress and Anger

No concrete relationship has yet been proven between the onset of pneumothorax and psychosomatic disorders [56, 57].

1.5 Aftercare

Re-expansion oedema may occur in pneumothorax patients after drainage of the pneumothorax and re-expansion of the lung. Clinically, this manifests with cough, shortness of breath, angina pectoris and expectoration of fluid bronchial secretion. Radiologically, there is a unilateral pulmonary oedema which can develop into bilateral pulmonary oedema. There is danger of acute respiratory failure with hypoxemia and need for artificial respiration. The risk of re-expansion oedema is determined by the extent of the lung collapse and the duration of pneumothorax prior to drainage [58].

E2	Recommendation	2017
Recommendation grade A	We recommend instructing patients on discharge to immediately contact a doctor if shortness of breath or chest pain occur.	
Evidence grad EC	Literature: Consensus of Experts	
	Consensus rate: 100 %	

All patients with pneumothorax should be instructed to immediately go to Emergency Admissions if pulmonary complaints develop again, independent of the performance of treatment.

Since there is no evidence for pneumothorax recurrence in connection with physical exertion, the patient can be advised to return to work and continue normal physical work after all symptoms have regressed. Sports which require extreme physical exertion and body contact should be postponed until complete lung expansion.

Patients with closed pneumothorax, which was treated conservatively, should refrain from flying until complete re-expansion of the lung has been confirmed by chest X-ray [59].

1.6 Recurrence Prophylaxis

1.6.1 Primary and Secondary Prevention

E3	Recommendation	2017
Recommendation grade A	We recommend informing the patient about the connection between smoking and the onset of pneumothorax and offering help to stop smoking.	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Bense 1987 [45] de Novo Research: Cheng 2009 [46], Hobbs 2014 [47], AWMF, S3-Guideline „Screening, Diagnostics and Treatment of Injurious and dependent tobacco consumption" 2015 [60]	
	Consensus rate: 100%	

Smoking increases the probability of developing pneumothorax in lung-healthy people and patients with prior pulmonary diseases [45–47]. For this reason, the person should refrain from smoking or help offered to stop smoking. It can be assumed that about 50% of smokers have a clinically-relevant dependence syndrome which cannot usually be ended without therapeutic intervention. The offers of professionally-conducted smokers' addiction treatment should be presented with the corresponding recommendations of the S3-guideline "Screening, Diagnostics and Treatment of Injurious Habitual Consumption of Tobacco" or the S3-guideline "Tobacco withdrawal in COPD" [60, 61].

E4	Recommendation	2017
Recommendation grade A	Diving should be avoided long-term, unless the patient underwent a bilateral pleurectomy in open surgery and has normal lung function and a postoperative CT examination of the thorax	
Evidence grade 3	Literature: Guideline adaptation BTS2010: Ziser 1985 [62], BTS guidelines on respiratory aspects of fitness for diving 2003 [63]	
	Consensus rate: 100%	

Following pneumothorax, diving with excess pressure bottles (scuba diving) should be advised against [62], unless a pleurectomy in both plural cavities was performed in open surgery [63].

2 Imaging of Pneumothorax

The following imaging procedures are used for the diagnostics and treatment of pneumothorax:

- Chest X-ray *p. a.* in inspiration
- Chest X-ray lateral view
- Chest X-ray *p. a.* in expiration
- Chest X-ray *a. p.* supine
- Sonographic examination of the chest
- CT chest

2.1 Chest X-ray

E5	Recommendation	2017
Recommendation grade A	We recommend a *p. a.* chest X-ray standing in inspiration for the initial diagnosis of pneumothorax.	
Evidence grade 1	Literature: Guideline adaptation BTS2010: Seow 1996 [64] de Novo Research: Thomsen 2014 [65]	
	Consensus rate: 100%	

2.1.1 Chest X-ray *p. a.* upright in Inspiration

This is the imaging of choice in identifying primary and secondary pneumothorax. The diagnostic characteristic is a shift in the pleural margin (lung bordered by the Pleura visceralis) with missing evidence of pulmonary vessel markings distal to the pleural margins. The finding of a soft-tissue emphysema is helpful in reaching the diagnosis.

It is difficult to determine the exact extent of the pneumothorax. The presence of bullous or cystic lung changes may lead to a false positive diagnosis of pneumothorax. In cases of uncertainty, a CT examination depending on the clinical relevance should be considered.

Digital X-rays have replaced conventional chest X-rays in hospitals in recent years. This has reduced the spatial resolution, but the possible magnification, measuring functions and contrast adjustments, simplified transmission, storage and reproduction possible with this technique are advantageous. In recent years there have been many technical advances, making digital imaging now just as reliable as the conventional chest X-ray in the diagnostics of pneumothorax.

The examinations should be reviewed on a dedicated x-ray interpretation console, since there are differences between the equipment provisions (screen size, number of pixels, contrast and luminescence) and thus also with respect to sensitivity of specialized equipment on the one hand and mobile desktops and user consoles on the wards on the other hand, which has a negative effect on image interpretation.

2.1.2 Chest X-ray lateral View

In an older study, a chest X-ray lateral view provided a helpful supplement to the *p. a.* image in 14% of the patients [66]. Recording a lateral view is no longer justified when the question concerns only "pneumothorax" and in PSP, but it is indicated in SSP and other indications.

2.1.3 Chest X-ray *p. a.* upright in Expiration

Many clinics still use these images for detection of a pneumothorax. No additional advantages can be anticipated in the routine evaluation of pneumothorax and the procedure is therefore not recommended [64, 65, 67, 68]. Contrary to this, examination in inspiration offers an advantage in the evaluation of the lung parenchyma to rule out other pulmonary abnormalities.

2.1.4 Chest X-ray Supine *a. p.* and lateral view

These imaging techniques are used for patients in Intensive Care. The images are less sensitive for diagnosing pneumothorax than the *p. a.* chest X-ray images in upright position [69, 70]. Subpulmonary pneumothorax can present in supine image by a broadening of the costophrenic angle (deep-sulcus-sign) [71–73]. More difficult to recognize is ventral pneumothorax, which presents – starting at a certain size – as a sharpening of the mediastinal/heart contour. X-ray examinations supine are supplemented by sonographic examinations and CT chest examinations especially in patients unable to stand.

2.2 Sonographic Examination

E6	Recommendation	2017
Recommendation grade B	We recommend sonographic examination by an adequately qualified examiner as an alternative to chest X-ray to rule out pneumothorax, especially postinterventional.	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Sartori 2007 [74] de Novo Research: Alrajab 2013 [75], Alrajhi 2012 [76], Ding 2011 [77], Jalli 2013 [78], Shostak 2013 [79], Vezzani 2010 [80], Volpicelli 2014 [81], Xirouchaki 2011 [82]	
	Consenus rate: 100 %	

Thoracic sonography is being increasingly used in the diagnostics of pneumothorax, especially in traumatology and intensive care medicine. Numerous studies have been published which showed that sonography is of great value in trauma diagnostics and is even superior to chest X-ray supine to rule out pneumothorax (▸ **Table 7**, Supplement). In a meta-analysis of 13 studies [75], thoracic sonography was compared to chest X-ray, whereby the CT-thorax was used as the reference method. Sonography attained a sensitivity and specificity of 78, resp. 98 % and chest X-ray of 39 and 99 %, with the limitation that only trauma patients were examined. Another area of sonography use is postinterventional diagnostics. Greater sensitivity and specificity of the technique compared to X-ray in supine position were found.

The most important sonographic criterion for pneumothorax is the lack of respiratory mobility of the lung in dynamic examination, the so-called lung sign. The diagnostic performance can be improved using a power doppler tool. Other sonographic criteria are a non-detectable pleural fissure, the lack of evidence of a so-called “comet-tail” artefact, the occurrence of repetition echoes and the depiction of a so-called “lung point” (transition between pneumothorax and aerated lung with contact to the chest wall) [83]. This is the most reliable criterion for proof of a pneumothorax in sonography. There are, however, technical limitations to the method, such as in soft-tissue emphysema, obesity, subpleural bullae, pleural adherences and due to regions inaccessible for sonography, such as subscapular or retrosternal. The diagnostic reliability of sonography also depends greatly on the experience of the examiner. The extent of a pneumothorax cannot be assessed sonographically.

2.3 Chest CT

E7	Recommendation	2017
Recommendation grade B	We suggest performing a CT examination only in cases where findings are unclear, in complicated constellations or if secondary spontaneous pneumothorax is suspected.	
Evidence gradeEC	Literature: Consensus of experts	
	Consensus rate: 100 %	

Computer tomography is the gold standard for imaging and assessing the lung parenchyma. The CT offers not only recognition of small pneumothoraxes, but also assessment of the precise dimensions. The greatest advantage of this examination is the identification of underlying bullae, of parenchymal diseases and of incorrect positioning of the thorax drainage. An HRCT-resolution (1 mm slice thickness with total coverage of the entire lung) must be demanded, since it offers greater sensitivity in the recognition of subpleural bullae (sensitivity 94–97 %) than a routine spiral-CT with reconstructions in 5 mm slice thickness (sensitivity 63–57 %) [84] or even greater slice thicknesses as in older studies [85].The risk for a recurrent ipsilateral spontaneous pneumothorax in patients with and without bullae in the CT was 68 resp. 6.1 %. The risk for a contralateral pneumothorax was 19 resp. 0 % [86].Moreover, modern CTs offer the possibility of multiplane reconstruction for precise assessment of the extent of the pneumothorax.

2.3.1 Indication for chest CT

The indications for a CT-examination are unclear findings, complicated constellations like initial soft-tissue emphysema, initial hematopneumothorax, severe concurrent disease, prior thoracic surgery or pneumothorax recurrence or for assessment of the parenchyma if secondary spontaneous pneumothorax is suspected. Contrast medium administration is not required for the assessment of the lung parenchyma.

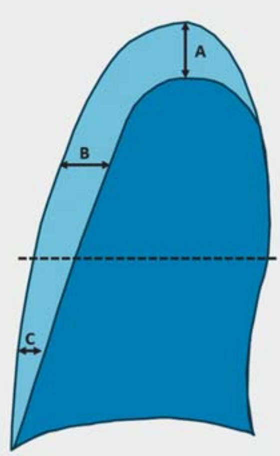
Looking at the epidemiological data, including mortality and concurrent diseases, it was found that both mortality and concurrent diseases increase starting at age 45. The use of a CT for more detailed diagnostics in pneumothorax appears sensible starting at this age, since it enables proof or exclusion of a concurrent lung disease. It thus makes an essential contribution to the definition of primary or secondary spontaneous pneumothorax with respect to influencing the further diagnostic and therapeutic strategy. A CT is associated with a considerably higher radiation exposure than a X-ray radiograph. A marked reduction in radiation exposure is also possible using the latest commercially available CT techniques. But these are not available everywhere, so no recommendation for the primary use of CT can be made [87].

2.4 Size of the Pneumothorax

E8	Recommendation	2017
Recommendation grade A	We recommend estimating the size of the pneumothorax based on a chest X–ray *p. a.* in inspiration as shown in ▶ **Fig. 2** (Collins Equation). A large pneumothorax is assumed if the sum of the measured values is ≥ 4 cm. (see ▶ **Fig. 4**)	
Evidence grade EC	Literature: Collins 1995 [88]	
	Consensus rate: 100 %	

The size of the pneumothorax is less important for the acute treatment than the patient's symptoms, since the size of the pneumothorax does not always correlate with the clinical symptoms Nonetheless, the size of the pneumothorax is an important indicator for a prolonged fistulisation after thorax drainage placement and the recurrence rate after conservative treatment. The size should therefore be determined and used for the primary assessment of the pneumothorax [89, 90]

The size of the pneumothorax is first determined in the chest X-ray *p. a.*, although this two-dimensional method may result in an underestimate of the actual three-dimensional pneumothorax size. For this reason, it is recommended that the interpleural distances in the apex area and lateral at the midpoints of the upper and lower halves of the collapsed lung should be measured (▶ **Fig. 4**), and therefore the volume of the pneumothorax can be better estimated by using the Collins equitation. [88]. The sum of the measured values of 4 cm corresponds to a pneumothorax of 20 % of the hemithorax volume. This value also corresponds to the borderline value for the definition of a small and large pneumothorax.



▶ **Fig. 4** Calculation of the size of the pneumothorax based on a chest X-ray *p. a.* in inspiration: Pneumothorax%= 4.2 + 4.7×(A+B+C). For this, the interpleural distances at the apex (A), lateral at the midpoints of the upper (B) and lower (C) halves of the collapsed lung are measured (Collins [88]).

A precise calculation of the pneumothorax volume is possible with the chest-CT as a three-dimensional method, either with time-consuming manual segmentation or automatic segmentation using special software. The precision of the method, however, has no additional clinical value in the treatment strategy.

3 Treatment of Primary Spontaneous Pneumothorax

Primary spontaneous pneumothorax (PSP) occurs in patients with no clinical evidence of underlying lung diseases. Although histological anomalies can almost always be found, especially associated with cigarette smoking, these have not manifested clinically in the form of symptoms or reduction of lung function. Differentiation from SSP is important, since PSP is associated with less dyspnoea. PSP also differs from SSP with respect to the extent of therapy and therapeutic success.

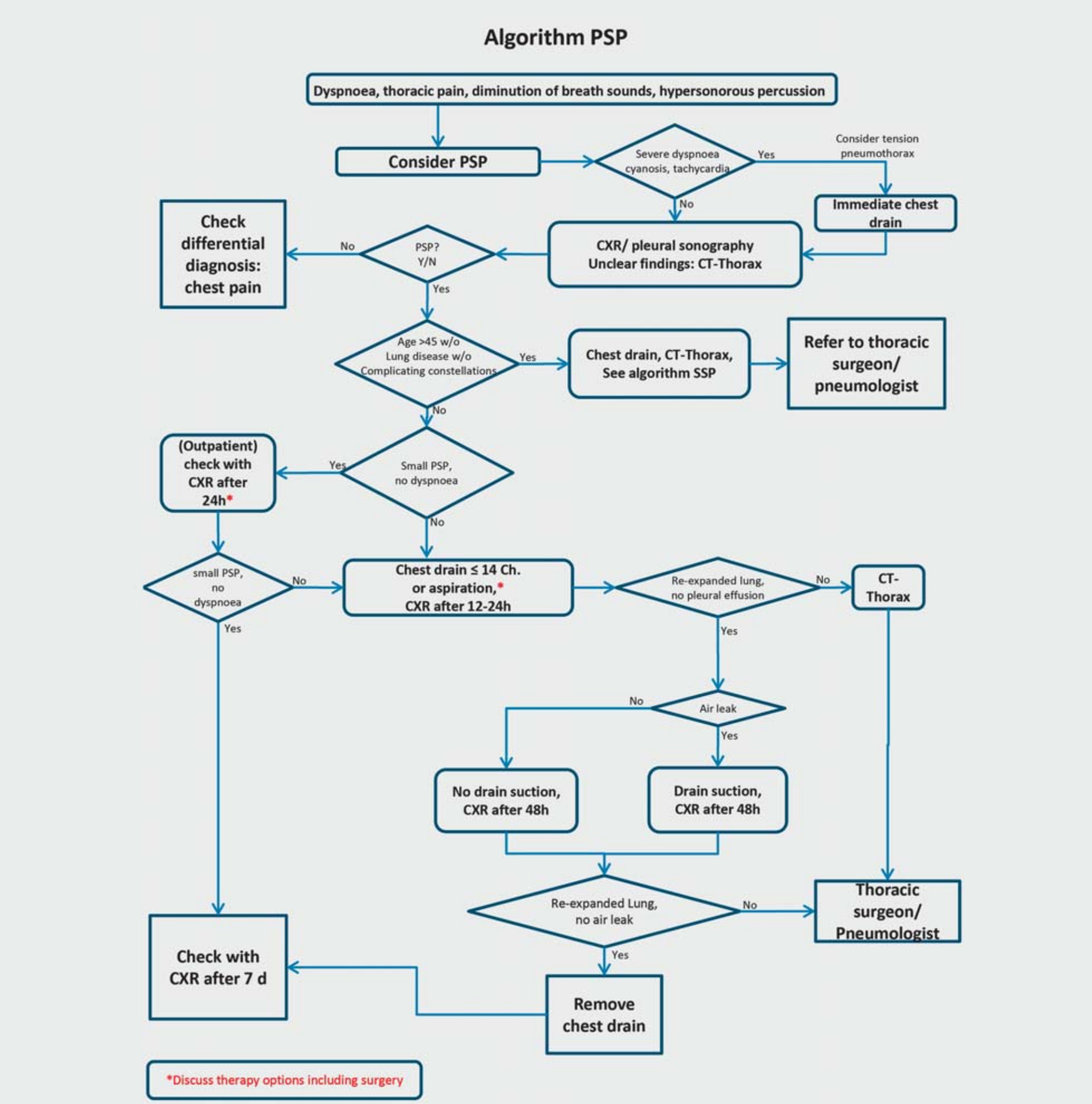
The diagnostic/therapeutic decisions discussed in the following sections are shown in the algorithm in ▶ **Fig. 5**.

3.1 General Treatment Strategy

E9	Recommendation	2017
Recommendation grade A	We recommend taking into consideration the size of the pneumothorax, the history (first event/recurrence) as well as the clinical symptoms in determining a treatment strategy of the PSP.	
Evidence grade 3	Literature: Guideline adaptation BTS2010: Flint 1984 [91], Stradling 1966 [92], Hart 1983 [93], O'Rourke 1989 [94] de Novo Research: Chiu 2014 [95], Ryu 2009 [90], Brown 2014 [10]	
	Consensus rate: 100 %	

E10	Recommendation	2017
Recommendation grade A	We recommend interventional treatment of patients with PSP and dyspnea, independent of the size of the pneumothorax.	
Evidence grade 3	Literature: Guideline adaptation BTS2010: O'Rourke 1989 [94] de Novo Research: Chiu 2014 [95], Ryu 2009 [90]	
	Consensus rate: 100 %	

E11	Recommendation	2017
Recommendation grade A	We recommend course observation in patients without dyspnea and small PSP.	
Evidence grade 3	Literature: Guideline adaptation BTS2010: Flint 1984 [91], Stradling 1966 [92], Hart 1983 [93]	
	Consensus rate: 100 %	



▶ **Fig. 5** PSP Flowchart.

After diagnosis of a PSP, the possible therapies and their advantages and disadvantages should be discussed in detail with the patient. There are no valuable, evidence-based studies on the indications for various therapeutic measures [96]. The available studies usually address only one aspect of the treatment success, without sufficiently taking into account other aspects like quality of life, long-term results or complications. For this reason, the indication for an intervention should be determined depending on the symptoms, pneumothorax history, radiological criteria, occupational anamnesis and the patient's wishes, particularly since, unlike in SSP, there is seldom a threat to life.

A conservative procedure has been found safe in a small PSP [10, 91–93]. Patients who have no dyspnoea can be treated as outpatients with instructions to return if the symptoms increase. Selected asymptomatic patients with large PSP can also simply be monitored [91]. An optional further appointment is advisable to control the radiological course. Correction of arterial hypoxemia [97] is indicated. The potential daily reduction rate of spontaneous pneumothorax was estimated at 1.25 to 2.2% of the total volume of the hemithorax [91, 98, 99]. The spontaneous total expansion of a complete pneumothorax can take 6 weeks, or even longer is there is a persistent air leak. For this reason, weekly control by chest X-ray to document resorption is sufficient in patients without complaints. The application of oxygen at high flowrates up to 16 l/minute led in one publication to a four-fold increase in the resorption rate of the pneumothorax [100]. However, a general recommendation for oxygen application cannot be made for conservative pneumothorax therapy.

Dyspnoea and a large pneumothorax are therapy-relevant findings [10, 90, 95]. Observation of the patient with dyspnoea alone is not appropriate. In this case, active interventions are necessary (needle aspiration or application of chest drain). Noticeable shortness of breath in patients with small spontaneous pneumothorax could herald a tension pneumothorax [94].

Both bilateral PSP and tension pneumothorax are potentially life-threatening events which make immediate intervention (application of thorax drainage) necessary due to the existing or to be expected dyspnea or cardiovascular depression.

3.2 Outpatient/Inpatient Treatment

E12	Empfehlung	2017
Recommendation grade A	We recommend emergency hospitalization of patients with bilateral PSP or tension pneumothorax.	
Evidence grade EC	Literature: Consensus of experts	
	Consensus rate: 93 %	

E13	Recommendation	2017
Recommendation grade B	We suggest outpatient treatment of patients with small PSP without dyspnoea after evaluation, with a required re-examination within 24 h.	
Evidence grade 3	Literaturs: Guideline adaptation BTS2010: Flint 1984 [91], Stradling 1966 [92], Hart 1983 [93], O'Rourke 1989 [94] de Novo Research: Massongo [101]	
	Consensus rate: 87 %	

Patients with primary bilateral PSP or tension pneumothorax usually have marked clinical symptoms. They should primarily be hospitalized until stabilization of the cardio-respiratory parameters. In these cases, concurrent initiation of thorax drainage is recommended

Asymptomatic patients with small PSP, by contrast, can be treated as outpatients [91–94, 101]. A clinical and radiological control after 24 hours is recommended. The resorption of the pneumothorax can be documented at weekly intervals by chest-X-ray [91–93, 101].

Patients with large PSP can also be treated as outpatients using small-lumen chest drains (8–14 Ch.). This requires a corresponding patient selection and an appropriate aftercare program. In studies with appropriately strict patient selection, an outpatient treatment quota of up to 50 % was possible [101–104].

3.3 Pneumological and Thoracic-Surgical Referral

E14	Recommendation	2017
Recommendation grade B	We suggest referral of patients with PSP and complicated constellation (such as initial soft-tissue emphysema, initial hematopneumothorax, serious concurrent disease, anticoagulative medication) to a thoracic surgeon or a pneumologist within the first 24 h.	
Evidence grade EC	Literature: Consensus of Experts	
	Consensus rate: 100 %	

Patients with a complicated constellation (such as initial soft-tissue emphysema, initial hematopneumothorax, serious concurrent disease, anticoagulative medication, prior thoracic surgery or pneumothorax recurrence), complications in the therapy of the pneumothorax (like soft-tissue emphysema, hematothorax, displaced drainage) or unsuccessful therapy (like insufficient re-expansion, persistent air leakage over 48 hours) should be examined by a pneumologist or thoracic surgeon. Such patients often require thorax drainage over a longer period with complex drainage management and possibly an operation and thus involvement of a thoracic surgeon [105]. It is also recommended that thorax drainage management be performed by nursing staff with the necessary expertise.

3.4 Needle Aspiration/Drain Therapy

E15	Recommendation	2017
Recommendation grade A	We recommend aspiration or small-lumen (≤ 14 Ch.) chest drain as the primary treatment of PSP requiring treatment.	
Evidence grade 1	Literature: Guideline adaptation BTS2010: Noppen 2002 [34], Harvey 1994 [106], Ayed [107], Masood 2007 [108], Devanand 2004 [109], Zehtabchi 2008 [110], Wakai 2007 [111], Vedam 2003 [112] de Novo Research: Ho 2011 [104], Aguinagalde 2010 [113], Nishiuma 2012 [114], Iepsen 2013 [115], Benton 2009 [116]	
	Consensus rate: 93 %	

E16	Recommendation	2017
Recommendation grade A	We recommend placement of a chest drain if aspiration is unsuccessful.	
Evidence grade 1	Literature: Leitlinienadaptation BTS2010: Noppen 2002 [34] de Novo Research: Aguinagalde 2010 [113], Nishiuma 2012 [114]	
	Consensus rate: 93 %	

E17	Recommendation	2017
Recommendation grade A	A chest drain must be applied for immediate therapy of bilateral PSP or tension pneumothorax	
Evidence grade EC	Literature: Consensus of Experts	
	Consensus rate: 100 %	

Both needle aspiration and application of a small-lumen chest drain (≤ 14 Ch.) are established procedures in the treatment of a PSP. Both procedures have been examined in several prospective randomized studies [34, 104, 106–108], systematic review articles [109, 111, 113] and meta-analyses [110, 113]. In a current Cochrane Review [117] of 6 RCTs, the primary treatment method (needle aspiration or small-lumen chest drain) showed a better primary success rate of drainage application, while the hospitalization time following aspiration is shorter. There were no significant differences in the hospitalization rate, the recurrence rate after one year, or in patient satisfaction.

If needle aspiration is performed, treatment after aspiration of more than 2.5 litres of air must be considered inadequate [34]. Needle aspiration is less painful than the application of a chest drain [106]. In case of lacking success (ca. 30 % of the patients), a second procedure in form of a chest drain will, however, be necessary [34, 113].

Small-lumen chest drain (≤ 14 Ch.) offer the same success rate as larger-lumen chest drain (> 14 Ch.) [112, 116], are less painful [118] and associated with a lower complication rate [115, 116]. Both the drainage time [115, 119] and the in-hospital treatment time were shorter for patients with small-lumen drainages [115, 116].

E18	Recommendation	2017
Recommendation grade A	We recommend pleurodesis via an indwelling chest drain in patients with PSP and high risk of recurrence or persistent pneumothorax, who are inoperable or refuse operative therapy.	
Evidence grade 1	Literature: Guideline adaptation BTS2010: Almind 1989 [120], Light 1990 [121] de Novo Research: Chen 2013 [36], Agarwal 2012 [122], How 2014 [123]	
	Consensus rate: 100 %	

The recurrence rate of pneumothorax can be reduced by means of pleurodesis via the chest drain. The recurrence rate after pleurodesis is, however, still considerably higher than following operative treatment of the pneumothorax, so that pleurodesis should be considered especially for patients with contraindication for operative treatment and for patients who refuse surgery. Possible substances for chemical pleurodesis are graduated talc [120], tetracycline [36, 120, 121, 123], povidone-iodine [122] and autologous blood [124]. The substances have been tested in several studies and all attained a reduction in recurrence rate compared to thorax drainage treatment alone. Because of induction of pleuritis with subsequent inflammatory reaction, pain, fever, and pleural effusions are frequent secondary effects, pleura empyema and pulmonary failure are rarer. These possible side effects and sometimes considerable complications must be considered in any case of indication for chemical pleurodesis. Since the introduction of thoracoscopic pneumothorax treatment in recurrence prevention, chemical pleurodesis via indwelling chest drain is used significantly less often.

3.5 Suction Therapy

E19	Recommendation	2017
Recommendation grade A	We recommend that suction therapy not be routinely performed after re-expansion.	
Evidence grade 1	Literature: Guideline adaptation BTS2010: So 1982 [125], Sharma 1988 [126], Reed 2007 [127]	
	Consensus rate: 93 %	

Symptomatic pneumothoraxes with large lung collapse require application of chest drain with suction [128]. Indication for using a suction system is also a persistent air leak (more than 48 hours with indwelling drainage) with or without incomplete re-expansion of the lung. There is no evidence for the routine use of suction [125–127].

The purpose of suction treatment is creation and maintenance of negative pressure in the pleural cavity. It is assumed that optimal suction should show pressure of − 10 to − 20 cm H_2O [129]. Digital systems, continuous measurement and recording of air leakages enable modern drainage management with shortening of the drainage time, length of hospital stay and reduction of treatment costs [130].

Re-expansion oedema may occur after placement of a chest drain. The incidence of the lung oedema depends on the size and duration of the pneumothorax [58, 131] and is up to 14 %, whereby the course of most cases is subclinical [131]. Clinical manifestations are cough, dyspnea, angina pectoris and expectoration of fluid bronchial secretion. In very rare cases, there is spread of the lung oedema to both lungs requiring intubation [132]. Patients with the clinical complaints cited above should be monitored in the ICU until the symptoms have abated.

3.6 Operation of the PSP

3.6.1 Indication for operative treatment of the primary spontaneous pneumothorax

E20	Recommendation	2017
Recommendation grade A	We recommend basing the indication for operation on the recurrence risk, life situation, patient preferences and procedure risk.	
Evidence grade EC	Literature: Consensus of experts	
	Consensus rate: 100 %	

E21	Recommendation	2017
Recommendation grade A	We recommend primary operative therapy of spontaneous hematopneumothorax.	
Evidence grade 3	Literature: Guideline adaptation BTS2010: Luh 2007 [133], Hwong 2004 [134]	
	Consensss rate: 100 %	

S6	Statement	2017
Statement	The following factors increase the risk of PSP recurrence: large pneumothorax, radiological-pathological changes in the lung or pleura, recurrent pneumothorax	
Evidence grade 4	Literature: de Novo Research: Chiu 2014 [95], Ryu 2009 [90], Chou 2010 [135], Tat 2014 [136], Ganesalingam [137]	
	Consensus rate: 100 %	

E22	Recommendation	2017
Recommendation grade A	We recommend surgery in persistent air leak or incomplete re-expansion under suction therapy and recurrent pneumothorax after aspiration or chest drain treatment.	
Evidence grade EC	Literature: Consensus of Experts	
	Consensus rate: 93 %	

In discussing the therapy options with the patient, the frequency of recurrence depending on the therapy (conservative/operative) must especially be presented (see ▶ **Table 3**). The low recurrence rates after operation are compared with the risks of the operation including postoperative complications and side effects like chronic pain [138, 139]. The indication for operation should be differentiated depending on symptoms, pneumothorax history, radiological criteria, occupational anamnesis and patient wish (see ▶ **Table 3**).

There is no evidence of an ideal timepoint for thoracic-surgical intervention in persistent air leakage or insufficient re-expansion of the lung. In the past, an OP-indication was mostly observed after 5 days [94]. This boundary is, however, arbitrarily selected; some colleagues tend to earlier [140] or later [141] intervention.

Surgical interventions per VATS have low morbidity of 2.4–9 % [142–147] and a low postoperative recurrence rate of 0–10 % [142, 143, 148, 149] (see ▶ **Table 4**).

In summary, in favour of operative treatment of a PSP are the lower risk of recurrence, harvesting of histology to clarify possible secondary genesis, shorter treatment time with low perioperative morbidity. Against the operation speak a possible overtreatment given the chance of conservative cure, postoperative side effects like pain, complications of the operation and that the operation can only be performed in hospital.

▶ **Table 3** Risk factors for recurrence on spontaneous pneumothorax

Recurrence risk factor	Recurrence frequency	Literature
X-ray/CT-Morphology (bullous changes)	▪ increased contralateral with bullae contralateral in 17 % – 27 % ▪ increased by 3–12-fold with conspicuous pleural features	Chou [135], Sihoe [151], Ganesalingam [137],
Pneumothorax size	▪ increased in large PSP to 26–70 %	Sayar [89], Ryu [90]Chiu [95], Tat [136]
Number of recurrences	▪ without prior recurrence: 5–54 % ▪ after 1st recurrence: 62–83 %	Bobbio [11], Brown [10], Olesen [35], Chen [36], Schramel [152], Sahn [153], Noppen [34], Aguingalde [113], Marquette [128], Jain [154], Gobe [155][l]

Radiological changes like a large pneumothorax/total atelectasis and pronounced bullous changes in PSP offer good support making the indication for surgery [10, 89, 90, 95, 136, 137]. The CT can be helpful in estimating the risk of recurrence. In these indications, but even when individually no essential risk of pneumothorax recurrence can be observed, patients may decide on operative treatment at the first PSP event. The patient's opinion plays a decisive role in reaching the decision [1]. With increased professional or hobby-related risk in case of recurrent pneumothorax (for example pilots, divers), the indication for operative treatment is given after the first event [53, 63, 150].

In patients with recurrent pneumothorax consulting of a pneumologist/thoracic surgeon is recommended (see recommendation 3.3.1).

3.6.2 Special aspects for strategy/technique of operative treatment of PSP

There are two essential therapeutic goals in the surgical therapy of pneumothorax with the treatment of a possible persistent air leakage and prophylaxis of recurrence. The first goal is to resect every visible perforation of the visceral pleura, as well as to identify and close emphysematous changes or pleural porosities on the surface of the visceral pleura. The second goal is pleurectomy and/or pleurodesis for prevention of recurrence.

▶ **Table 4** Recurrence frequency, length of treatment, complications/side effects in various forms of therapy of spontaneous pneumothorax

Therapy option/Author	Recurrence frequency	Length of treatment Inpatient/outpatient	Complications Side effects
Observation			
Brown [10] Stradling [92] Hart [93] O'Rouke [94]	after 1 year: 5 % [10]; 6 % [92] after ≥ 2 years: 6 % [92], 21 % [93], 32.5 % [94]	Up to 7 weeks outpatient	O'Rouke [94]: 2 deaths with tension pneumothorax Brown [10]: 23 % with later operation
Aspiration			
Noppen [34] Ayed [107] Nishiuma [114]	after 1 year: 26 % [34]; 22 % [107]; 36 % [114] after 2 years: 31 % [107]	26–52 % inpatient, 0–7 days inpatient	Ayed [107]:Analgesics in 34 %
Chest drain			
Brown [10] Noppen [34] Olesen [35] Chen [36] O'Rouke [94] Ho [104] Ayed [107] Aguingalde [113] Iepsen [115]	after 1year: 17 % [10]; 27.3 % [34], 24 % [107] ≥ 2 years 23.5 % [94];25 % [107]; 1–6 years: – 54 % [35]	4–20 days inpatient	Second drain/procedure in 15 % – 24 % [10, 94, 104, 113] Ayed [107]: Analgesics in 56 % Iepsen [115]: Bleeding in 4.9 %, Wound infection in 4.8 %, Soft tissue emphysema in 8.1 %
Pleurodesis			
Chen [36] Almind [120] Light [121] Agarwal [122]	8–29.2 %	2–6 days inpatient	Almind [120]:Pain in 58 % (Talcum) resp.74 % (Tetracycline) Agarwal [122]: Pain, hypotension, empyema
VATS			
Chiu [95] Barker [142] Vohra [143] Min [148] Chen [149] Pages [155] Foroulis [156] Joshi [157] Chou [158] Czerny [159] Passlick [138]	0–10 %	2.4–10 days	Vohra [143]: VATS better than thoracotomy with respect to analgesic use, postoperative lung function Pages [155]:Complications in 8 % Foroulis [149]:Complications in 5–7.5 % Joshi [156]: Complications in 9 % Czerny [159]: Operative revision in 2.4 % Passlick [138]: Chronic pain syndrome in 31.7 %
Open OP (Thoracotomy)			
O'Rouke [94] Granke [140] Barker [142] Vohra [143] Thevenet [144] Weeden [145] Korner [146] Thomas [147] Pages [155] Foroulis [156] Joshi [157]	0–5 %	4.2–18.4 days inpatient	O'Rouke [94]:Wound infection (5 %) Granke [140]: in 5 %: Wound infection, respiratory failure, bronchopleural fistula, inadequate wedge resection. Weeden [145]: Major complications in 3.8 % (death, bleeding, art. respiration), Minor complications in 16.7 % (contralateral/apical pneumothorax, empyema, phlegm retention, wound infect, thrombosis) Korner [146]: Complications in 16 %, 30d-mortality 1 % Joshi [157]: 7.5 % bleeding postoperative, 16 % ICU

3.6.2.1 Route of Access: Videoassisted Thoracic Surgery (VATS) vs. open Thoracotomy

E23	Recommendation	2017
Recommendation grade A	We recommend video-assisted surgery (VATS) for the operative treatment of pneumothorax.	
Evidence grade 1	Literature: Guideline adaptation BTS2010: Al-Tarshihi 2008 [160], Barker 2007 [142], Vohra 2008 [143], Inderbitzi 1994 [161], Deslauriers 1980 [162], Waller 1994 [163], Sedrakyan 2004 [164], Dumont 1997 [165], Mouroux 1996 [166], Bertrand 1996 [167], Gebhard 1996 [168], Cole 1995 [169], Sekine 1999 [170] de Novo Research: Pages 2015 [155], Foroulis 2012 [156], Joshi 2013 [157], Chou 2012 [158], Balduyck 2008 [171]	
	Consensus rate: 100 %	

E24	Recommendation	2017
Recommendation grade A B	We recommend partial pleurectomy or talcum poudrage to reduce the risk of recurrence in VATS. We suggest an additional atypical resection of the lung apex.	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Thevenet 1992 [144] de Novo Research: Chen 2012 [149], Nakanishi 2009 [172], Sepehripour 2012 [173], Ingolfsson 2006 [174]	
	Consensus rate: 100 %	

E25	Recommendation	2017
Recommendation grade 0	In recurrence of a surgically-treated PSP, the patients can be offered talcum pleurodesis or reoperation (VATS or thoracotomy).	
Evidence grade EC	Literature: Consensus of Experts	
	Consensus rate: 100 %	

Over the past several years, VATS has become established in the operative treatment of spontaneous pneumothorax rather than open thoracotomy. Accepting a slightly higher risk of recurrence with VATS (1 vs. 4%) [142, 143] is offset by its advantages over open thoracotomy, such as less bleeding [157, 160], reduced postoperative intensive care monitoring [157], milder postoperative pain [160, 163, 164, 168, 170], a better postoperative pulmonary gas exchange [163, 170] and shorter stay in hospital [157, 160, 163–165, 167, 169]. The shorter stay in hospital after VATS could not be confirmed by all investigators [175, 176]. Patient satisfaction is higher for VATS than for thoracotomy [156].

3.6.2.2 Pleurectomy/surgical pleurodesis

The recurrence rate after thoracoscopic bulla resection alone in PSP is higher than in open thoracotomy with bulla resection so that an additional pleural intervention in VATS is recommended to reduce the recurrence rate [172, 174].

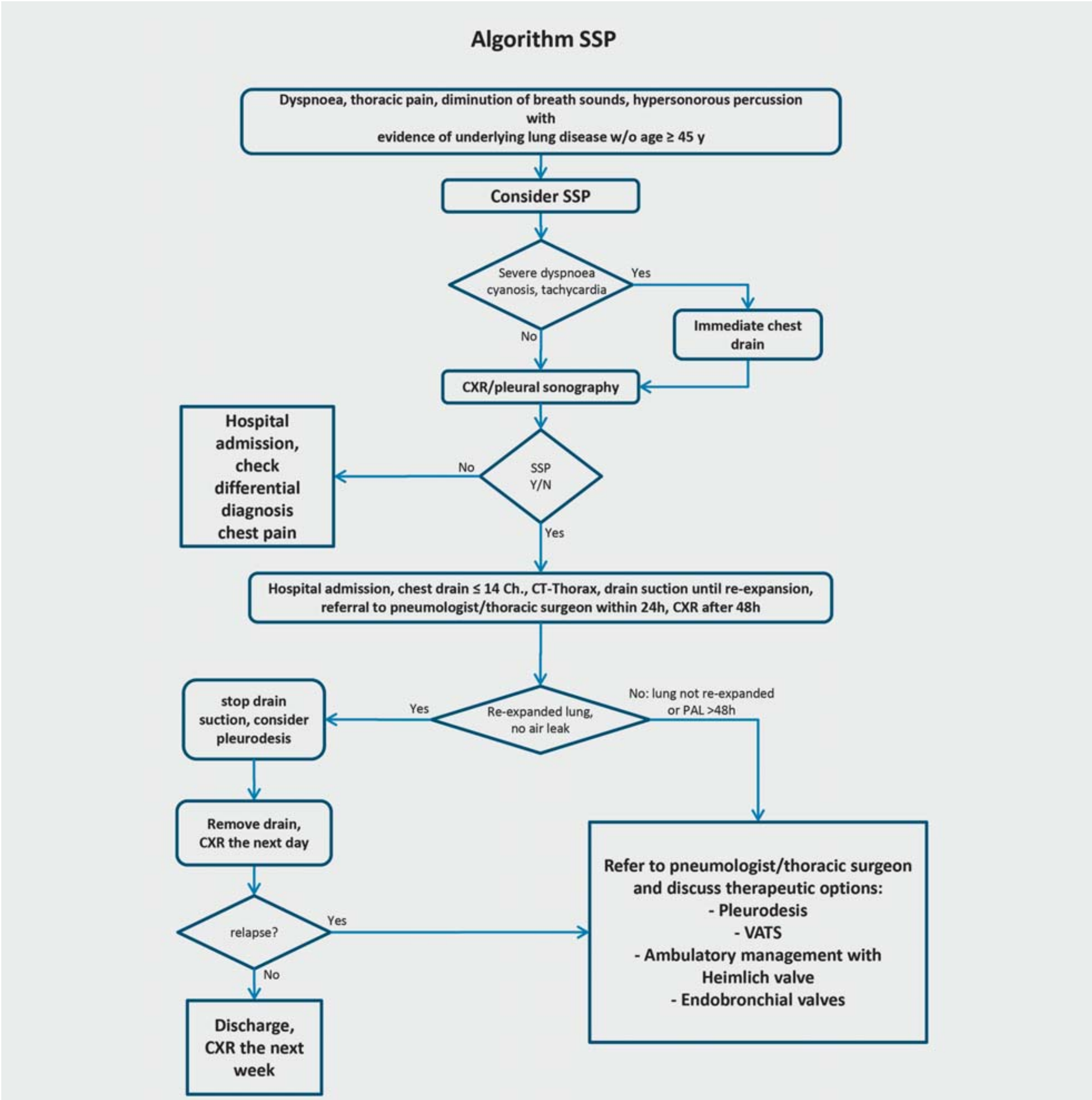
Partial parietal pleurectomy is established as a standard procedure in the treatment of pneumothorax, frequently in combination with a pleurodesis procedure [142, 143, 174]. There are no randomized studies on pleurectomy with wedge resection versus wedge resection alone. Comparative studies [149, 177] on apical pleurectomy versus abrasion of the pleura found a longer operation time and increased morbidity (bleeding) in the patients with pleurectomy with equal recurrence rates of 5% resp. 4%. In 2014, Min [148] could demonstrate that an abrasion of the pleura in addition to wedge resection on the lung brings no advantages in the sense of reduced recurrence rate (6% in both groups after 2 years). Bulla resection in addition to intraoperative chemical pleurodesis also only increases the incidence of fever and prolongs postoperative hospitalization, but the risk of recurrence cannot be reduced [178]. The recommendation for pleurectomy is based on retrospective studies, which are in part contradictory to recent randomized studies.

Reports to date have shown that freedom from recurrence can be achieved in 85–90% of cases using talcum poudrage [179–181]. A meta-analysis on the success rate of talc poudrage in the treatment of pneumothorax showed a composite success rate in 22 retrospective studies of 91% [180]. Graduated talc is superior to tetracycline, which has a higher recurrence rate [182].

After talc poudrage, there is a possibility of SIRS resp. Acute Respiratory Distress Syndrome (ARDS) [183, 184]. The incidence of postoperative empyema is very low with proper sterilization of the talc [180]. The ARDS after talc application, which was greatly feared in the past, is very rare with the graduated talcum of particle size > 10 µm used these days [184].

4 Treatment of Secondary Spontaneous Pneumothorax and of Special Cases of Spontaneous Pneumothorax

Unlike primary spontaneous pneumothorax (PSP), secondary spontaneous pneumothorax (SSP) occurs in patients with an underlying lung disease, most frequently with chronic obstructive lung disease (COPD). Patients older than age 45 suffering from a pneumothorax do have an increased probability of an existing lung disease, which was possibly not diagnosed earlier. In patients older than 45 years of age, the in-hospital mortality and the frequency of pulmonary concurrent diagnoses increase significantly (see ▶ **Figs. 2** and **3** in Chapter 1). For this reason, performance of a CT-thorax in patients 45 or older with spontaneous pneumothorax appears sensible. The treatment algorithm of SSP differs from that of PSP and is presented in ▶ **Fig. 6**.



▶ **Fig. 6** SSP Flowchart.

4.1 General Treatment Strategy

S7	Statement	2017
Statement	In determining a treatment strategy for SSP, the size of the SSP is less important than the degree of clinical impairment occurring with the SSP	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Tanaka 1993 [7], Norris 1968 [8] de Novo Research: Brown 2014 [10]	
	Consensus rate: 100 %	

In general, the symptoms of SSP are more serious than those of PSP. Most patients with SSP suffer new onset or increasing dyspnoea [7]. The size of the pneumothorax correlates poorly with the symptoms, hypoxemia is usually more pronounced in SSP [7, 8, 10].

E26	Recommendation	2017
Recommendation grade A	We recommend the application of a chest drain and supportive treatment (including oxygen administration) in SSP with newly-occurring or increasing dyspnea.	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Tanaka 1993 [7], Chee 1998 [141], Schoenenberger 1991 [185], O'Driscoll 2008 [186] de Novo Research: Brown 2014 [10]	
	Consensus rate: 100 %	

In a SSP, spontaneous closure of air leakage is less likely than in a PSP [141, 185] and the patients have more frequent and more serious symptoms [7], which is why most of these patients require a chest drain. A retrospective study showed longer median time under drainage therapy to spontaneous closure of persistent air leakage for patients with SSP (11 days) than for patients with PSP (7 days) [9].

Aspiration of the pneumothorax is thus not broadly used in SSP. Oxygen administration is indicated in hypoxemia, whereby the danger of hypercapnia is known and should be countered by control of blood gases [186]. In the rare cases of asymptomatic patients with small, typically apical pneumothorax, initial drainage treatment can be dispensed with in favour of course observation, as an exception.

4.2 Outpatient/Inpatient Treatment

E27	Recommendation	2017
Recommendation grade A	We recommend hospitalization of patients with SSP.	
Evidence grade 2	Literature: de Novo Research: Brims 2013 [187], Voisin 2014 [103]	
	Consensus rate: 100 %	

Despite low evidence, the elevated in-hospital mortality of up to 16 % [12] and the frequency of comorbidities speak for the primary in-hospital treatment of SSP (see ▶ **Figs. 2**, **3** in Chapter 1). In a stable situation, outpatient treatment may be considered after thoracic-surgical and pneumological assessment, even with indwelling chest drain (for example using a Heimlich valve) [103, 187]. On discharge, it is advisable to instruct the patient to return immediately to the hospital if dyspnoea increases. In outpatient drainage treatment, we recommend thoracic-surgical or pneumological aftercare until the pneumothorax is completely resorbed.

4.3 Pneumological/Thoracic-surgical Assessment

E28	Recommendation	2017
Recommendation grade A	We recommend pneumological and/or thoracic-surgical assessment within the first 24 hours of hospitalization in SSP.	
Evidence grade EC	Literature: Guideline adaptation BTS2010 de Novo Research: Aslam 2011 [105]	
	Consensus rate: 100 %	

E29	Recommendation	2017
Recommendation grade A	We recommend an interdisciplinary pneumological/thoracic-surgical assessment to determine further therapy measures in the case of inadequate re-expansion or persistent air leakage over 48 hours.	
Evidence grade EC	Literature: Guideline adaptation BTS2010 de Novo Research: Aslam 2011 [105]	
	Consensus rate: 100 %	

E30	Recommendation	2017
Recommendation grade A	SSP may be an expression of an advanced, serious rare lung disease. In this case, we recommend further treatment of the lung disease in specialized centres.	
Evidence grade 4	Literature: de Novo Research: Nakajima 2009 [16], Ichinose 2016 [188] Ota 2014 [15]	
	Consensus rate: 100 %	

Interdisciplinary pneumological/thoracic-surgical assessment of a patient with SSP is to be recommended, both initially and in cases of inadequate re-expansion of a pneumothorax or persistent air leakage over 48 hours. The treatment of SSP can be complex and should be conducted in facilities where specialized medical and nursing knowledge is available [105]. A pneumological assessment of the underlying or newly-diagnosed lung disease is required.

The mortality of SSP depends on the basic disease [15, 16, 188]. In the presence of rare lung diseases, such as interstitial lung diseases or cystic fibrosis, prompt transfer to a hospital with appropriate expertise for the examination and full use of additional therapy options (lung replacement procedure, lung transplantation) is to be recommended.

4.4 Drainage Therapy

E31	Recommendation	2017
Recommendation grade A	We recommend use of a small-lumen drain (≤ 14 Ch.) when chest drainage is indicated in patients with SSP.	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Tsai 2006 [189] de Novo Research: Benton 2009 [116], Iepsen 2013 [115], Contou 2012 [190]	
	Consensus rate: 100 %	

Four retrospective studies showed no difference in the effectiveness between small-lumen (up to 14 Ch.) and large lumen chest drains [115, 116, 189, 190]. It was shown that small-lumen thorax drainages are less painful, lead to fewer inflammatory complications and bleeding [115, 116] and to shorter indwelling times [115, 116, 190]. Caution is required with high fistula volume and small drainages. As in PSP, drainage treatment of SSP is continued until spontaneous closure of the air leakage. The indications for other therapy options must be checked if there is no spontaneous closure of the air leakage.

E32	Recommendation	2017
Recommendation grade A	We recommend that suction therapy is not routinely continued after re-expansion	
Evidence grade 1	Literature: Guideline adaptation BTS2010: So 1982 [125]	
	Consensus rate: 100 %	

The indication for drainage therapy with suction is incomplete re-expansion of the lung. In a randomized study including 30 patients with SSP, the drainage duration with (up to 20 cm H_2O) versus without suction was, however, equal [125]. The study also showed that removal of the drain is better with an interval of two days rather than immediately after complete re-expansion of the lung ($p < 0.1$).

Digital drain systems can possibly objectify the size of the air leak, especially with intermittent fistula. Approximation of the air leakage can be obtained after connection of a sealed bag with valve function (see Supplement on Chest Drainage).

E33	Recommendation	2017
Recommendation grade A	We recommend chemical pleurodesis or autologous blood via an indwelling chest drain in patients with SSP in expanded lung and persistent air leakage or recurrent pneumothorax, if an operation is contraindicated.	
Evidence grade 1	Literature: Guideline adaptation BTS2010: Light 1990 [121], Almind 1989 [120] de Novo Research: Agarwal 2012 [122], Aihara 2011 [191], Cao 2012 [192], Ng 2010 [193]	
	Consensus rate: 100 %	

The indication for pleurodesis is persistent air leakage or a recurrent SSP, if an operation is not possible or desired. Prerequisite to success is complete expansion of the lung. Substances which have been investigated in this indication are talc, autologous blood, tetracycline and povidone-iodine (see ▶ **Table 5**).

4.5 Further Non-operative Therapy Options

E34	Recommendation	2017
Recommendation grade B	As possible non-operative therapy options for patients with therapy- refractive SSP, we recommend interdisciplinary discussion of indwelling drainage (outpatient or inpatient) and endobronchial-blocking procedures.	
Evidence grade 5	Literature: de Novo Research: Travaline 2009 [194]	
	Consensus rate: 100 %	

When operation is contraindicated or pleurodesis via drainage unsuccessful, remaining therapy options which could be considered, despite weak evidence, are endobronchial-blocking procedures with application of valves [194] and application of indwelling drainage

4.6 Operation of the secondary spontaneous pneumothorax

The goals of the operation in secondary spontaneous pneumothorax are the same as in primary spontaneous pneumothorax: elimination of the persistent air fistulas and recurrence prophylaxis. For this reason, the same operative measures of bullae resection for fistula closure, pleurectomy and/or pleurodesis for prophylaxis of recurrence are used. For general operation management, see the previous chapter on therapy of PSP. In this chapter, the special aspects in the operative therapy of SSP, which may be challenging for the surgeon, are presented.

Table 5 Substances for chemical pleurodesis via indwelling drainage

Author	Study type	Substance/Dose	Effect	Side effects
Agarwal [122]	Systematic Review and Meta-Analysis (13 Studies with 138 patients)	20 ml 10 % Povidone-iodine in 80 ml NaCl	Pooled success rate 88.7 % (95 % CI 84.1–92.1)	Thoracic pain, hypotension
Aihara [191]	Retrospective 59 SSP in ILD	50 ml autologous blood, minocycline 200 mg in 50 ml NaCl, OK432 (Picibanil) 10 KE in 50 ml NaCl	Success with blood in 72.7 %, Pleurodesis success in 78.6 %	Recurrence in 50 % (blood) vs. 45 % (chemical pleurodesis), Exacerbation 2× after chemical pleurodesis
Cao [192]	Randomized-controlled 44 Pat with SSP in COPD	0.5 vs. 1 vs. 2 ml/kg autologous blood vs. NaCl	Success with 1 and 2 ml/kg in 82 %, mostly repeated administration	
Ng [193]	Retrospective 121 SSP with Minocycline, 64 SSP with talc	Minocycline 300 mg in 100 ml NaCl Talc 2,5–5 g Suspension in 100 ml NaCl	Success minocycline 78 % Success talcum 72 %	Thoracic pain in 45 % (minocycline) vs. 37.5 % (talcum)
Light [121]	Prospective randomized study in 229 PSP/SSP	1500 mg tetracycline in 50 ml NaCl over 1–2 h vs. NaCl	Success with tetracycline in 75 % vs. 59 % without	"severe chest pain" in 61 % despite local anesthesia
Almind [120]	96 SP 18–88 years of age	550 ml tetracycline in 20 ml Aqua vs. 5 g talc in 250 ml NaCl over 2 h	Success with tetracycline in 87 %, talcum in 92 %	Pain in 74 % (tetracycline) vs. 58 % (talcum)

The patient collective in SSP differs from that in PSP by a usually higher age, underlying lung disease with limited lung function and more frequent concurrent diseases. These circumstances result in a greater risk for surgery and anaesthesia and influence the indication and the OP technique. Postoperative persistent air leakage is significantly higher in SSP than in PSP (31 % vs. 4 %, P < 0.05,) [195].

4.6.1 Indication for operative treatment of secondary spontaneous pneumothorax

E35	Recommendation	2017
Recommendation grade A	We recommend individually determining the indication for operation in SSP aimed at fistula closure and measures for recurrence prophylaxis, taking into consideration underlying disease, comorbidities and patient wish	
Evidence grade 3	Literature: Guideline adaptation BTS2010: Passlick 2001 [138] de Novo Research: Pages 2015 [155], Park 2014 [196], Ichinose 2016 [188],Isaka 2013 [197], Nakajima 2009 [16], Zhang 2009 [198], Balduyck 2008 [171]	
	Consensus rate: 100 %	

In selected patients, the operation in SSP had a recurrence rate of 12 % and less [155, 188, 196, 197]. The in-hospital mortality in operated patients with obstructive pulmonary disease (COPD) is significantly lower than in patients with interstitial lung disease (1,3 vs. 15–21 %) [16, 188].The recurrence rate, too, is significantly lower in operated patients with COPD than with pulmonary fibroses (12 vs. 35 %) [188, 197]. Concurrent diseases and the extent of the lung disease play a role in determining the indication for operation. Thus, in 2009, Zhang [198] found in a retrospective study of 107 COPD patients older than 60 a significantly increased complication rate in hypercapnic patients than in patients with normocapnia. The 30-day mortality in this cohort was 4.7 %.

The patient's preference should be part of the decision-making, weighing the advantages of the reduced rate of recurrence and improved quality of life resulting from the operation [171] against possible complications [138].

E36	Recommendation	2017
Recommendation grade A	Caution is recommended in setting the indication for operative treatment of pneumothoraces in fibrosing lung diseases and wherever possible giving preference to a pleurodesis procedure via indwelling drainage.	
Evidence grade 4	Literature: de Novo Research: Nakajima 2009 [16], Ichinose 2016 [188] Ota 2014 [15]	
	Consensus rate: 100 %	

Interstitial lung diseases (synonym diffuse parenchymatous lung diseases) frequently develop recurrences of a pneumothorax; especially LAM, combinations of fibroses with emphysema and fibrosing ILDs. Since the respiratory reserve is frequently limited by the lung disease, especially in fibrosing ILDs, even a small pneumothorax may lead to respiratory decompensation. Application of drainage is urgently indicated in such cases.

Several retrospective studies [16, 188] report high recurrence rates and higher in-hospital mortality after operation of a pneumothorax with lung fibrosis compared to pneumothorax operation with COPD (21.4 % vs. 1.4 % and 15 % vs. 2 %). The indication for operative treatment of a pneumothorax in fibrosing lung disease should be used with caution.

E37	Recommendation	2017
Recommendation grade A	We recommend coordinating the therapy with the transplantation center in the case of pneumothorax in a potential lung transplant recipient.	
Evidence grade EC	Literature: de Novo Research: Shigemura 2012 [199]	
	Consensus rate: 100 %	

SSP is a frequent event among candidates for lung transplantation. Usually these patients have very advanced lung disease with a high operative risk. In a monocentric US American study, [199] 23 % of 554 lung-transplant recipients (70 % bilateral) had undergone prior thoracic surgery (8 % pleurodesis, 9 % thoracic-surgical procedures, 6 % cardiosurgical interventions). Patients with previous pleurodesis had a 1.8-fold higher risk of dying postoperative after lung transplantation than patients without pleurodesis. Thus, pleurodesis complicates the later lung transplantation. The indication for pleurectomy/pleurodesis should therefore be made with caution and, whenever possible, after consultation with the transplantation centre.

4.6.2 Special Aspects of Strategy/Technique in the operative treatment of SSP

E38	Recommendation	2017
Recommendation grade A	We recommend orienting the operative strategy in SSP to individual aspects of the lung disease and imaging (CT).	
Evidence grade 4	Literature: Guideline adaptation BTS2010: Thevenet 1992 [144] de Novo Research: Nakajima 2009 [16], Ichinose 2016 [188]	
	Consensus rate: 100 %	

Since SSP is based on a heterogeneous group of lung diseases, the operation technique should be adapted to the specific situation [16, 188]. It is essential to adapt the required lung parenchymal resection in SSP with COPD to the sometimes-pronounced bullous changes so that the lung region fistulizing into the pleura is resected. An intraoperative water probe prior to resection can be helpful if the location of the fistula is unclear. A more extensive pleurectomy or pleurodesis may be required for recurrence prophylaxis in diffuse lung disease than is the case in PSP [144].

4.6.2.1 Access path: VATS versus open thoracotomy

E39	Recommendation	2017
Recommendation grade A	We recommend minimally-invasive operative treatment of SSP.	
Evidence grade 1	Literature Guideline adaptation BTS2010: Barker 2007 [142], Sekine 1999 [170], Vohra 2008 [143] de Novo Research: Foroulis 2012 [156], Joshi 2013 [157], Qureshi 2008 [200], Pages 2015 [155], Park 2014 [196]	
	Consensus rate: 100 %	

In recent years, the operative procedure per VATS in the treatment of pneumothorax has become established worldwide. In Germany between 2011 and 2015, only about 12–13 % of the pneumothorax operations were performed via open thoracotomy [12].

VATS has advantages over the open procedure, namely quicker mobilization [156], slighter early-postoperative pulmonary function limitations [142, 170], shorter hospitalization time [157] and lower need for pain relievers [143, 170, 200]. These advantages are of especial importance for patients with SSP, limited lung function and multimorbidity. The disadvantage of VATS lies in an elevated recurrence rate [142, 155]. For this reason, Pages [155] and Qureshi [200] recommend considering the indication for an open procedure in patients with SSP and risk of recurrence. Park [196] showed retrospectively in 40 patients with SSP shorter drainage and hospitalization time for the VATS technique compared to the open operation with the same rate of recurrence.

4.6.2.2 Intraoperative Pleurectomy/Pleurodesis

E40	Recommendation	2017
Recommendation grade A	We recommend using parietal pleurectomy or alternatively a pleurodesis procedure as recurrence prophylaxis in the operative treatment of SSP.	
Evidence grade 1	Literature: Guideline adaptation BTS2010: Barker 2007 [142], Vohra 2008 [143], Ingolfsson 2006 [174], Tschopp 1997 [181], Lee 2004 [201], Thevenet 1992 [144], Maskell 2004 [184] de Novo Research: Qureshi 2008 [200]	
	Consensus rate: 100 %	

Partial parietal pleurectomy has become established as the standard procedure in the treatment of pneumothorax, frequently in combination with pleurodesis procedures [142, 143, 174]. Thevenet could determine a slight advantage for pleurectomy [144].

Intraoperative in SSP, adhesions of the Pleura parietalis with the Pleura visceralis were observed. Since in intraoperative pleurolysis, parenchymal defects may arise with the danger of postoperative prolonged air leak, intraoperative pleurodesis (argon beamer, povidone-iodine, tetracyclines, talcum) should be applied in cases of extensive pleura adhesions instead of pleurectomy.

Thoracoscopic pleurodesis with intraoperative administration of 3–5 g talc achieves a recurrence-free rate of 90 % [181]. Lee [201] could retrospectively observe freedom from recurrence of 95 % over 3 years in SSP with COPD per thoracoscopic talc pleurodesis in LA with a mortality of 10 %. In a retrospective study of 61 patients with SSP, Kim [202] could demonstrate that thoracoscopic bulla resection with talc pleurodesis is clearly superior to pleurodesis with talc administration ("Slurry") via the thorax drainage with respect to the recurrence rate (4.5 % vs. 30 %).

ARDS after talc administration, which was feared in the past, is rare with the graduated talcum with particle size > 10 µm used today [184].

4.7 Special Cases of Pneumothorax

4.7.1 Catamenial Pneumothorax

S8	Statement	2017
Statement	The presence of a catamenial pneumothorax and/or a thoracic endometriosis is possible in women of childbearing age with spontaneous pneumothorax.	
Evidence grade 3	Literature Guideline adaptation BTS2010: Alifano 2007 [31] de Novo Research: Rousset-Jablonski 2010 [32]	
	Consensus rate: 100 %	

E41	Recommendation	2017
Recommendation grade B	We recommend gynaecological co-assessment for further diagnostics and therapy in suspected cases.	
Evidence grade 3	Literature: Guideline adaptation BTS2010: Alifano 2007 [31] de Novo Research: Rousset-Jablonski 2010 [32]	
	Consensus rate: 87 %	

In women of childbearing age with spontaneous pneumothorax, a temporal connection between pneumothorax and the menstruation cycle should be actively sought and the patient questioned about period occurrence of thoracic pain, about infertility and about gynaecological operations. If catamenial pneumothorax is suspected, a gynaecological examination and an MRT of the pelvis are recommended [32]. Intraoperative, diaphragm defects and pleural endometriosis foci should be sought and, if present, closed, respectively biopsied. The operation alone has a recurrence rate of up to 30 % [31]. In combination with a GnRH analogon, the recurrence rate can be reduced, but amenorrhea must be accepted.

4.7.2 Pneumothorax in Pregnancy

E42	Recommendation	2017
Recommendation grade A	We recommend close cooperation between thoracic surgery/pneumology and obstetrics in recurrent pneumothorax in pregnancy, based on the BTS Guideline.	
Evidence grade 3	Literature: Guideline adaptation BTS2010: Terndrup 1989 [33], Lal 2007 [203]	
	Consensus rate: 100 %	

E43	Recommendation	2017
Recommendation grade A	We recommend orienting treatment principles for pneumothorax during pregnancy on those for PSP, taking the special situation and possible risks for mother and foetus into consideration.	
Evidence grade 3	Literature: Guideline adaptation BTS2010: Terndrup 1989 [33], Lal 2007 [203]	
	Consensus rate: 100 %	

There appears to be a greater risk of recurrence for patients with spontaneous pneumothorax during pregnancy and birth [33, 203]. In the absence of prospective studies, therapy of pneumothorax during pregnancy is oriented to the recommendations for treatment of PSP cited above, whereby the individual risks for the patient and the foetus must be taken into account. In pneumothorax during pregnancy, therefore, a co-assessment by the thoracic surgeon, pneumologist and obstetrician should be conducted early and the further treatment made at a qualified facility.

5 Postinterventional Pneumothorax

5.1 Introduction

The postinterventional pneumothorax is important because of the high number of thoracic interventions. The highest incidence occurs in thoracentesis, while transbronchial lung biopsy, pleural effusion puncture and puncture of central veins on the upper thorax aperture are associated with a much lower risk of pneumothorax (▶ **Table 6**). Among the methods of endoscopic lung volume reduction (▶ **Table 6**), the implantation of endobronchial valves is especially associated with a relevant rate of pneumothorax. The treatment of postinterventional pneumothorax is usually uncomplicated, apart from patients with serious underlying lung diseases.

▶ **Table 6** Summary of thoracic intervention and pneumothorax risk or rate of thorax drainage in pneumothorax.

Procedure	postinterventional pneumothorax (%)	chest drain/pneumothorax (%)	Author
Transthoracic lung biopsy	2.8–59.6 % Median: 23.7 %	0–48.5 %	Ayyappan 2008 [204], Chakrabarti 2009 [205], De Filippo 2014 [206], Asai 2013 [207], Gupta 2008 [208], Hiraki 2010 [209], Kahn 2008 [210], Nakamura 2011 [211], Vatrella 2014 [212], Accordino 2015 [213], Anderson 1994 [214], Choi 2004 [215], Covey 2004 [216], Fish 1987 [217], Garcia-Rio 1996 [218], Geraghty 2003 [219], Kim 2015 [220], Topal 2003 [221], Vitulo 1996 [222], Sartori 2007 [74]
Transbronchial biopsy	2.9–7 % Median: 2.9 %	31–100 %	Huang 2012 [223], Izbicki 2006 [224], Kreuter 2011 [225], Kumar 2015 [226], Reißig 2005 [227],
Transbronchial cryobiopsy	28 %	73 %	Casoni 2014 [228]
Pleura puncture	0.61–6.0 % Median: 5,2 %	9.1–44.4 %	Gordon 2010 [71], Ault 2015 [229], Colt 1999 [230], Doyle 1996 [231], Pihlajamaa 2004 [232]
Central vein puncture	0.66–7–6 % Median: 0.9 %	0–100 %	Vezzani 2010 [80], Shieh 2015 [233], Harrington 1995 [234], Kirkfeldt 2012 [235], Kirkfeldt 2014 [236]
Implantation endobronchial valve	8.3–25.6 % Median: 15 %	83,3–100 %	Davey 2015 [237], Klooster 2015 [238], Herth 2013 [239], Valipour 2016 [240]
Coil Implantation	5–11.6 % Median: 6 %	k. A.	Shah 2013 [241], Deslee 2016 [242], Sciurba 2016 [243]
Vapor ablation	2.2 %	0 %	Herth 2016 [244]

5.2 Recommendations

E44	Recommendation	2017
Recommendation grade A	After a thoracic intervention with pneumothorax risk, we recommend observation until clinical or radiological/sonographic exclusion of pneumothorax 1–4 hours after the intervention.	
Evidence grade 4	Literature: de Novo Research: Choi 2004 [215], Kim 2015 [220], Doyle1996 [231],Pihlajamaa 2004 [232]	
	Consensus rate: 100 %	

The literature [215, 220, 224, 231, 232, 245, 246] confirms that a vast majority of postinterventional pneumothoraxes could be proven within 4 hours by symptoms or imaging procedures. Accordingly, the risk of later-onset pneumothorax is slight. The patient should be informed on discharge about the risk of pneumothorax and to return immediately to the hospital if the corresponding complaints arise.

The possibility of a late pneumothorax must be taken into account especially after implantation of endobronchial valves [237, 247]. The rate of postinterventional pneumothoraxes after coils and other endoscopic procedures in volume reduction is markedly lower. In the available studies, the postinterventional X-ray diagnostics immediately followed the intervention. Further controls by chest X-ray should be symptom-oriented.

E45	Recommendation	2017
Recommendation grade B	We suggest dispensing with routine imaging procedures in stable patients without clinical signs of a pneumothorax, especially in the following situations: ▪ after thoracentesis if only one needle passage was required and no air was aspirated. ▪ after transbronchial lung biopsy, if this was performed with biopsy forceps and no persistent desaturation events occur in the post-observation phase.	
Evidence grade 4	Literature: de Novo Research: Doyle1996 [231], Pihlajamaa 2004 [232], Du Rand 2013 [248]	
	Consensus rate: 100 %	

Based on the evidence [224, 231, 232, 248, 249] the Guideline Group assumes that in the vast majority of uncomplicated pleura effusion punctures and transbronchial forceps biopsy, postinterventional X-ray diagnostics does not influence the management of the patient and that the radiation exposure involved can be avoided. This procedure can be considered safe if the patient is under structured control for at least 2 hours postinterventional, including monitoring of typical pneumothorax symptoms, and the patient is informed on discharge of the possibility of a late pneumothorax and given appropriate instructions for behaviour in such a situation. This recommendation should not, however, be extended to transbronchial cryobiopsy, since this method of material harvesting is associated with a considerably higher pneumothorax rate (28 %), especially in fibrosing parenchymal diseases [228] (▶ **Table 6**).

E46	Recommendation	2017
Recommendation grade B	We suggest, given adequate expertise, using pleurasonography in the diagnostics of postinterventional pneumothorax as an alternative to chest X-ray.	
Evidence grade 2	Literature: Guideline adaptation BTS2010: Shostak 2013 [79], Sartori 2007 [74] de Novo Research: Garofalo 2006 [250], Kreuter 2011 [225], Kumar [226], Reißig 2005 [227]	
	Consensus rate: 100 %	

Sonographic examination of the thorax after intervention shows high sensitivity and specificity, as several studies [74, 79, 225–227, 250] on sonographic diagnostics in postinterventional pneumothorax confirm (see **Table S2**, Supplement).

For this reason, the Guideline Group assumes that chest sonography can be considered at least as good as chest X-ray in the diagnostics of postinterventional pneumothorax, given adequate experience of the examiner. It can even offer advantages in certain situations in which chest X-ray in the standard technique is not possible (such as bedridden patients, intensive care unit). If the situation remains unclear based on sonography, radiological diagnostics should follow. This may also be necessary for quantification of a sonographically detected pneumothorax, since the size can be estimated sonographically to only a limited degree.

E47	Recommendation	2017
Recommendation grade A	In patients without dyspnoea and small postinterventional pneumothorax, we recommended course observation. In case of large or symptomatic pneumothorax, we recommend application of a chest drain.	
Evidence grade 4	Literature de Novo Research: Nour-Eldin 2009 [251], Nour-Eldin 2011 [252]	
	Consensus rate: 100 %	

There are no prospective controlled or randomized studies of the criteria for when active therapy is indicated in postinterventional pneumothorax. In the published case reports, which are mostly retrospective, there is agreement that both a clinical criterion and a size criterion should apply, whereby the former takes precedence over the latter [191, 204, 208, 209, 211, 251–253].

The extent of the pneumothorax is defined in accordance with the Chapter "Imaging of pneumothorax" [88]. Thus, the indication for application of a chest drain is given in symptomatic patients or patients with large pneumothorax.

E48	Recommendation	2017
Recommendation grade A	As therapy of choice, we recommend initiating small-lumen thorax drainage with application of suction.	
Evidence grade 4	Literature: de Novo Research: Ayyappan 2008 [204], Malone 2013 [253], Gupta 2008 [208], Nour-Eldin 2009 [251], Nour-Eldin 2011 [252]	
	Consensus rate: 93 %	

There are no prospective controlled or randomized studies on the size of drainage and the application of suction. In the mostly retrospective case series, drain sizes from 8–22 Ch. were used [204, 208, 251–253]. Outpatient treatment of postinterventional pneumothorax with drain and Heimlich valve has also been described in case series and is feasible [208]. If this method is ineffective, however, application of suction via an underwater seal under hospital conditions is usually necessary [204, 208, 253]. Usually, these are patients with underlying lung disease. For this reason, the principles of treatment of secondary spontaneous pneumothorax are applicable.

E49	Recommendation	2017
Recommendation grade 0	If a pneumothorax occurs under a CT-assisted intervention, single aspiration can be performed if the extent and symptoms are moderate. If the symptoms or size expansion of the pneumothorax cannot be controlled by this procedure, we recommend application of a chest drain.	
Evidence grade 4	Literature: de Novo Research: Nour-Eldin 2011 [252], Yamagami 2009 [254]	
	Consensus rate: 100 %	

Single aspiration of a postinterventional pneumothorax has been investigated in the literature primarily in connection with CT-assisted interventions. The available single-arm uncontrolled studies [252, 254] do not show scientific proof that the application of a chest drain can be avoided with a single aspiration of postinterventional pneumothorax. Manual aspiration can be considered as an alternative to immediate application of a chest drain, if the pneumothorax under the intervention is of moderate size (< 2 cm).

E50	Recommendation	2017
Recommendation grade A	In persistent air leak (> 5 days) or inadequate expansion of the lung, we recommend consultation with a thoracic surgeon.	
Evidence grade EC	Literatur: Consensus of Experts	
	Consensus rate: 100 %	

Even though evidence is largely lacking, the Guideline Group considers reasonable the definition of a time interval after which additional interventions should be considered if air leakage persists or the lung does not fully inflate after the chest drain has been initiated. We recommend consultation with a pneumologist/thoracic surgeon as described for PSP/SSP after 24 or 48 hours.

E51	Recommendation	2017
Recommendation grade A	Pneumothorax-specific after-care measures or behavioural limitations in everyday life are not necessary after a postinterventional pneumothorax.	
Evidence grade EC	Consensus of Experts	
	Consensus rate: 100 %	

We not recommend any specific after-care measures or behavioural limitations in everyday life after an interventional pneumothorax.

There are no prospective studies on after-care following post-interventional pneumothorax. The behavioural rules following spontaneous pneumothorax apply and are cited in the corresponding chapter.

Supplement

▶ **Tables 7** and **8**.

▶ **Table 7** Rating of thorax sonography for the diagnostics of Pneumothorax

Author	Study type	Patient collective	Sono		X-ray	
			sensitivity	specivicity	sensitivity	specivicity
Abbasi et al., Eur J Emergeny Med 2013 [255]	Prospective not randomized diagnosis study	N = 153 post trauma	86.4 %	100 %	48,6 %	100 %
Alrajab et al. Critical Care 2013, 17:R208 [75]	Review and metaanalysis	N = 1514, mostly post-trauma	78.6 %	98.4 %	39.8 %	99.3 %
Alrajhi, Chest 2012 [76]	Systematic review and meta-analysis	N = 1048, X-ray in 864 patients, mainly post-trauma	90.9 %	98.2 %	50.2 %	99.4 %
Ding et al., Chest 2011 [77]	Meta-analysis	Mainly trauma or after intervention	88 %	99 %	52 %	100 %
Jalli, Emerg Radiol, 2013 [78]	Prospective not randomized diagnosis study	N = 197 post-trauma	80 %	89 %	61 %	98 %
Kreuter et al., Ultraschall Med 2011 [224]	Prospective not randomized diagnosis study	N = 1023 post- bronchoscopic intervention	100 %	83 %		
Refaat, Egyptian J Radiol Nucl Med, 2013 [256]	Prospective diagnosis study	N = 90, Intensive medicine with respiratory failure	92 %	100 %		
Sartori, AJR 2007 [74]	Prospective diagnosis study	N = 285, post-ultrasound-assisted lung biopsy	100 %	100 %	87 %	100 %
Shostak, J Ultrasound Med 2013 [79]	Prospective diagnosis study	N = 185, post-intervention	75/88 %	97 %		
Vezzani Crit Care Med 2010 [80]	Prospective diagnosis study	N = 111, after central venous catheters	N = 4		N = 2	
Volpicelli Intensive Vare Med 2014 [81]	Prospective diagnosis study	N = 124 mit pneumothorax, spontaneous, post-trauma or intervention	81,4–88,2 %	64,7–72,6 %		
Xirouchaki Intensive Care Med 2011 [82]	Prospective diagnosis study	N = 42 respirated patients	75 %	93 %		

▶ **Table 8** Studies on performance of pleurasonography in the diagnostics of post-interventional pneumothorax

Author	Intervention	Ref. Method	PTX total	PTX in PS	PTX in CXR	Sensitivity	Specificity	Accuracy	US limitied
Shostak 2013 [79]	PP n = 60 TBB n = 48 CT-TTNB n = 77	CXR	n = 8 4 %	n = 7 3.8 %	n = 8 4 %	88 %	97 %	97 %	n = 47 25.4 %
Garofalo 2006 [249]	CT-TTNB n = 184	CT & CXR	n = 46 25 %	n = 44 23.9 %	n = 19 10.3 %	95.6 %	100 %	98.1 %	n = 0 0 %
Kreuter 2011 [224]	TBB n = 1023	CXR	n = 30 2.9 %	n = 36§ 3.5 %	n = 30 2.9 %	100 %	83 %	99 %	n = 6§ 0.6 %
Kumar 2015 [225]	TBB n = 113	CXR	n = 8 7 %	n = 8 7 %	n = 7 6.2 %	100 %	100 %	100 %	k. A.
Reißig 2005 [226]	TBB n = 35 pPD n = 18	CXR	n = 4 7.5 %	n = 4 7.5 %	n = 3 5.7 %	100 %	100 %	100 %	k. A.
Sartori 2007 [74]	Sono-TTNB n = 285	CXR	n = 8 2.8 %	n = 8 2.8 %	n = 7 2.4 %	100 %	100 %	100 %	k. A.

PTX = Pneumothorax; PS = Pleurasonography; CXR = Chest X-ray; US limited = limited sonar conditions (pleural effusion, pleural callosity, bulla, obesity); PP = Pleural puncture; TBB = transbronchial biopsy; CT-TTNB = CT-assisted transthoracic needle biopsy; pPD = transient pleural drainage; Sono-TTNB: sonography-controlled transthoracic needle biopsy; CT = Computertomography; k. A.= not cited; §: 6 false-positive findings in the pleurasonography (Abolition of lung movement due to pleural adhesions). In all 6 cases, pneumothorax could be definitively ruled out in chest X-ray.

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