



ERS task force statement: diagnosis and treatment of primary spontaneous pneumothorax

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ABSTRACT Primary spontaneous pneumothorax (PSP) affects young healthy people with a significant recurrence rate. Recent advances in treatment have been variably implemented in clinical practice. This statement reviews the latest developments and concepts to improve clinical management and stimulate further research.

The European Respiratory Society's Scientific Committee established a multidisciplinary team of pulmonologists and surgeons to produce a comprehensive review of available scientific evidence.

Smoking remains the main risk factor of PSP. Routine smoking cessation is advised. More prospective data are required to better define the PSP population and incidence of recurrence. In first episodes of PSP, treatment approach is driven by symptoms rather than PSP size. The role of bullae rupture as the cause of air leakage remains unclear, implying that any treatment of PSP recurrence includes pleurodesis. Talc poudrage pleurodesis by thoracoscopy is safe, provided calibrated talc is available. Video-assisted thoracic surgery is preferred to thoracotomy as a surgical approach.

In first episodes of PSP, aspiration is required only in symptomatic patients. After a persistent or recurrent PSP, definitive treatment including pleurodesis is undertaken. Future randomised controlled trials comparing different strategies are required.



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A European Task Force reviews scientific evidence and suggests future research for primary spontaneous pneumothorax <http://ow.ly/MWhuF>

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Introduction

Spontaneous pneumothorax was first described in 1819 by LAËNNEC [1] and has been traditionally categorised as primary or secondary spontaneous pneumothorax (PSP and SSP, respectively). PSP is defined as a spontaneous pneumothorax occurring in patients without a prior known underlying lung disease [2]. It remains the subject of ongoing debate, despite important progress achieved in both medical and surgical treatments.

PSP is associated with low rates of morbidity and mortality, typically affects a young population and has a recurrence rate of between 17% and 54% [3–7]. Aetiological mechanisms of PSP are better appreciated following contemporary pathophysiological studies [8, 9]. The last few decades have seen advances in both the diagnosis and the treatment of spontaneous pneumothorax. Some newer approaches, however, remain poorly implemented in standard clinical practice [4, 6, 10–17]. The European Respiratory Society (ERS) is updating this statement regarding PSP in order to present the latest developments and concepts, with the aim of improving clinical management and stimulating further high quality research in this important area.

Methods

During the 2012 ERS Annual Congress in Vienna (Austria), a European Task Force was formed of 12 clinical and scientific experts, comprising seven pulmonologists and five surgeons from eight European countries. The Task Force was established according to the recommendations of the ERS Scientific Committee for development of a statement that is a comprehensive scientific review by a group of experts (table 1). The statement is based on a body of scientific evidence identified by systematic searches and documented by references supporting the conclusions [18]. Initially, a set of key clinical questions in five sections was formulated on epidemiology, diagnosis, classification, treatment of first episode and treatment of recurrent or complicated PSP. To obtain a body of scientific evidence, a systematic literature search was performed on medical databases (Medline/PUBMED (National Library of Medicine, USA), EMBASE (Elsevier, the Netherlands), Cochrane Library (UK)) by the librarian of the University of Geneva Faculty of Medicine (Geneva, Switzerland) under the supervision of a Task Force member (J-M. Tschopp). The initial search was performed in February 2013 and repeated in September 2014. The search was limited to reference material regarding adult patients published since 1993. Well-balanced subgroups of two to four members, including both pulmonologists and thoracic surgeons, prepared first drafts for each section. In the first plenary session, all sections were read and discussed and a consensus was established. A subsequent writing committee (J-M. Tschopp, G. Cardillo, N. Maskell and O. Bintcliffe) prepared a second draft that was sent to all Task Force members, who provided written feedback. A third draft was prepared by the writing committee and revised again by all Task Force members. A final draft was discussed and approved in a final plenary session during the 2014 ERS International Congress in Munich (Germany). The final document therefore represents the consensus of the Task Force members. This statement describes the current evidence and practices for PSP. It does not make recommendations for clinical practice. This statement has been endorsed by the ERS Scientific Committee.

TABLE 1 Methodology checklist

	Yes	No
Panel assembly		
Experts from chest medicine and thoracic surgery	x	
Experts vetted for conflict of interest	x	
Patient representative	x	
Expert methodologist	x	
Literature review		
Performed in collaboration with librarian	x	
Searched in multiple electronic databases (Medline/PUBMED, EMBASE, Cochrane Library)	x	
Reviewed reference list of retrieved articles	x	
Evidence synthesis		
Prespecified inclusion and exclusion criteria applied		x
Evaluation of included studies for source of bias	x	
Explicitly summarised benefits and harms	x	
Grading system used		x
Included studies evaluated		
Recommendations for clinical practice		x
Summary/opinions	x	

Epidemiology of primary spontaneous pneumothorax

The incidence of PSP in a population around Stockholm (Sweden) between 1975 and 1984 was 18 per 100 000 per year in males and six per 100 000 per year in females [19]. Between 1991 and 1995, combined annual rates of primary and secondary pneumothorax in England were 24 per 100 000 for men and 9.8 per 100 000 for women in a study analysing three national databases [20]. Annual costs in the USA have been estimated at \$130 million [21].

The most important risk factor for PSP is tobacco smoking. The retrospective study in Stockholm assessed the smoking rates of 138 patients admitted to hospital over a 10-year period and compared their rates of smoking with a large contemporary random sample of people from the same area. Of the patients with PSP, 88% smoked. Compared with nonsmokers, the relative risk of a first spontaneous pneumothorax was increased nine-fold in women and 22-fold in men who smoked [19]. Additionally, a strong dose–response relationship was detected in this study between risk of pneumothorax and number of cigarettes smoked per day [19].

Cannabis smoking shares common pathological processes and an overlapping spectrum of lung disease with tobacco smoking; however, cannabis smoke has been demonstrated to be particularly associated with bullous disease. Multiple large peripheral bullae at the lung apex are often seen in young patients with a history of cannabis smoking, in the absence of significant parenchymal damage elsewhere. In addition, the duration of exposure is shorter than would be expected in the development of these abnormalities due to tobacco smoke alone [22]. Differences in the physical mechanism of inhalation when smoking cannabis are described as being a potential explanation for the development of this accelerated pattern of lung damage that predisposes to pneumothorax [23–25].

Cases of PSP have been shown to exhibit clustering, an effect that has been hypothesised to be due to changes in atmospheric pressure [26] or levels of air pollution [27]. Height has been demonstrated to be a risk factor for PSP [28] and recent studies have shown a high prevalence of low body mass index (BMI) in patients with PSP [29].

Catamenial pneumothorax is a rare condition that affects women of reproductive age, in a temporal relationship with menses. These recurrent episodes of pneumothorax occur within 72 h before or after the start of menstruation. Catamenial pneumothorax is thought to be underdiagnosed, with a recent large retrospective study showing it to be the underlying cause in over 30% of pre-menopausal women who were surgically treated for spontaneous pneumothorax [30]. Although catamenial pneumothorax is often associated with the presence of thoracic endometriosis, most commonly the only abnormalities seen at the time of surgery are diaphragmatic defects [31]. They can be single or multiple, are usually located at the central tendon, and range in size from tiny holes (1–3 mm) to larger defects (>10 mm) [31]. Therefore, at the time of surgery, the diaphragm, parietal pleura, lung and pericardium are inspected meticulously, any diaphragmatic holes are repaired and any thoracic lesions resected and sent for histological analysis [32]. Despite these measures, the recurrence rate is high (32% in one series [33]), leading some authors to suggest the administration of a gonadotrophin-releasing hormone analogue (leading to amenorrhoea) for 6–12 months after surgery [31, 34].

The onset of PSP typically occurs at rest (80%) and is characteristically associated with chest pain (81%) and dyspnoea (39%) [35]. The incidence of recurrence of PSP is reported to range between 17% and 54% in the first year following pneumothorax [4, 7]. Pneumothorax as a whole has a bimodal age distribution: PSP peaks between the ages of 15 and 34 years and SSP in those aged >55 years [20].

In summary, smoking tobacco remains the main risk factor for PSP. Marijuana smoking also increases the risk of pneumothorax [36]. More prospective data are required to better define the population at risk and the true incidence of recurrence.

Clinical evaluation of primary spontaneous pneumothorax

Symptoms

Typically, patients present with an abrupt onset of pleuritic chest pain with or without breathlessness and some patients may experience shoulder tip pain [37]. Commonly, symptoms are minimal or even totally absent, in contrast to the presentation of secondary pneumothorax, in which breathlessness is a predominant feature. Symptoms usually improve following presentation of PSP; a worsening of symptoms is very rare and when it occurs, it suggests the development of complications (such as haemopneumothorax) or an alternative aetiology.

Clinical examination

Typical examination findings in PSP include reduced or absent breath sounds, reduced ipsilateral chest expansion and hyper-resonant percussion [38]. Haemodynamic compromise or significant hypoxia is

unusual in primary pneumothorax [39]. In view of the variability of symptoms and signs at presentation, the diagnosis of primary pneumothorax is usually confirmed with radiographic imaging.

Chest radiograph

Posterior-anterior chest radiographs remain the standard examination in patients with suspected PSP and may be combined with lateral radiographs in difficult cases [40]. The radiographic hallmark is displacement of the pleural line and an absence of lung markings between the edge of the pleura and chest wall. The value of routine expiratory films in the diagnosis of pneumothorax has been evaluated in studies with paired inspiratory and expiratory chest radiographs and has demonstrated that pneumothoraces can be reliably diagnosed with inspiratory radiographs alone [41, 42].

Computed tomography

Computed tomography (CT) is more sensitive than chest radiographs in the detection of pneumothorax [43–46]. However, it is not required in the majority of cases, as the diagnosis may be clearly made on a chest radiograph and an excess radiation dose should be avoided in this young patient population [47]. It may be possible to adjust the imaging protocol to minimise radiation dose depending on the indications for imaging. Cross-sectional imaging may be useful in complicated cases, in suspected tube misalignment, where underlying lung disease is suspected [48] and in patients requiring surgery.

Ultrasound

In the past decade, lung ultrasonography has emerged as a sensitive technique in the evaluation of respiratory diseases, and it has gained a well-established role in the diagnosis of pneumothorax in trauma and critically ill patients [45, 49–54]. Recent studies have evaluated ultrasound in trauma patients, in whom it has shown a sensitivity of 98%, a negative predictive value of 82% and a positive predictive value of 100% [55]. These studies showed significantly higher diagnostic yield with ultrasound than chest radiographs, with CT used as the reference examination [56–58]. The routine use of ultrasound in PSP, however, has not yet been well established.

Classification and pathophysiology of pneumothorax

The distinction between primary, secondary, traumatic and iatrogenic pneumothorax is important in view of the different management strategies required for their treatment.

A spontaneous pneumothorax occurs in the absence of any identified extrinsic cause. PSP occurs in the absence of clinically apparent underlying lung disease, while SSP occurs as a complication of a pre-existing underlying lung disease such as chronic obstructive pulmonary disease [59, 60], cystic fibrosis [61–63], lung malignancy (primary or metastatic) or necrotising pneumonia of various causes [64–67].

The distinction between PSP and SSP is becoming increasingly blurred, as patients with PSP may be found to have subtle undiagnosed pulmonary abnormalities on further investigation [68, 69]. This may lead to an alternative classification system in the future.

Recurrent pneumothorax is defined as a subsequent episode of pneumothorax occurring after either an ipsilateral or contralateral pneumothorax.

Tension pneumothorax occurs when the intrapleural pressure becomes greater than the atmospheric pressure throughout all phases of respiration. It can be seen in ventilated patients or after trauma or cardiopulmonary resuscitation, but is extremely rare in PSP [70].

Size of the pneumothorax

The estimation of the size is traditionally based on the Light index [71]:

$$\text{Size of PSP(\%)} = \left(1 - \left(\frac{\text{Average lung diameter}^3}{\text{Average hemithorax diameter}^3} \right) \right) \times 100$$

A study used this method and found a strong correlation between the estimated size and the volume of air removed from the pleural space during drainage [18]. However, a comparison between the estimated size of a pneumothorax using the Light index and CT volumetrics, derived by the Collins method, found poor agreement between the methods [72]. The average difference was 7.3%, with the Light index underestimating the size relative to the Collins method. The 95% limits of agreement were wide (24% underestimation to 17% overestimation of size), demonstrating that the Light index does not accurately estimate the size of pneumothorax [73].

Although CT scanning is the best method of measuring the size of the pneumothorax, a precise estimate of size has little clinical value. There is considerable variability in previous international guidelines on the treatment for pneumothorax. There is general agreement that treatment is required for clinically compromised patients. For clinically stable patients, treatment recommendations have been based, at least in part, on the size of pneumothorax (small or large), although the definition of a large pneumothorax differs [6, 21]. A study comparing the size classifications used by the different guidelines demonstrated poor agreement between them [72], and there is no contemporary evidence to support the approach of treatment decisions based on size of pneumothorax alone. Most Task Force members adopt a symptom-driven approach, with follow-up to ensure resolution, rather than basing initial management on size alone.

Pathophysiology

The precise pathogenesis of PSP is not completely understood. With the improvement of imaging techniques, blebs and bullae can be visualised ipsilaterally or bilaterally in almost all patients with PSP during surgery, medical thoracoscopy or CT scan [74–77]. These changes visible on the visceral pleura have been called emphysema-like changes (ELCs), which are also recognised as a specific entity. Recently, in a subset of patients with spontaneous pneumothorax, fibroblastic lesions consisting of pleural fibrosis with islands of fibroblastic foci within a myxoid stroma have been described [78]. It is generally believed that pneumothorax results from the rupture of ELCs, based on a hypothesis of VANDERSCHUEREN [79], who thought that there was a continuous evolution from normal pleura to blebs and then progressive larger bullae rupturing leading to occurrence of PSP; however, this has never been proved. Sites of lung rupture are difficult to demonstrate during surgery or on resected pieces of lung [80–82]. Two studies compared the appearance of blebs and bullae in first episode and recurrence of PSP and did not find any significant differences in size, number or location of blebs and bullae, either by medical thoracoscopy or CT scan [83, 84], raising doubts about the aforementioned assumption [79] and the role of blebs and bullae rupture as the main factor explaining the occurrence of PSP. More recently, CASALI *et al.* [85], using high-resolution CT scans, developed a new severity score for abnormalities of the visceral pleura in PSP and demonstrated a significant correlation between the severity of this score and the risk of recurrence of PSP at follow-up. These results, obtained in a retrospective series, require confirmation in prospective studies but do suggest a population at risk who may benefit from more invasive treatment.

Thorough examination of resected specimens of lung in cases of PSP does not demonstrate macro- and microscopic sites of air leakage [86] but diffuse areas of disrupted mesothelial cells in the visceral pleura, replaced by a layer of inflammatory cells with increased “elastofibrosis process” and pores of 10–20 mm in diameter, suggesting the presence of diffuse pleural porosity [80, 86, 87]. The development of a new technique of fluorescein-enhanced autofluorescence thoracoscopy [88] clearly showed many areas of fluorescein leakage on the visceral pleura even in normal areas, as seen by normal light, lending weight to the idea of diffuse pleural porosity. These diffuse histological changes on the visceral pleura may explain the high recurrence rate (20%) following bullectomy alone without an associated pleurodesis [82, 89–91].

This also leads to an important practical question: what is the respective weight of blebs, bullae and ELCs in the aetiology of air leakage (fig. 1). There is evidence that the presence of ELCs and pleural porosity is related to other factors, such as patient height, distal airway inflammation, hereditary predisposition, low BMI and abnormal connective tissue, which may predispose to PSP [70].

In summary, the true role of rupture of blebs and bullae as a cause of air leakage in spontaneous pneumothorax is not clear [92].



FIGURE 1 A piece of resected lung parenchyma in a case of recurring primary spontaneous pneumothorax. Image courtesy of A. Spiliopoulos (Faculty of Medicine, University of Geneva, Geneva, Switzerland).

Treatment of first episodes of primary spontaneous pneumothorax

Overall, treatment of PSP has two goals: evacuation of air, if necessary, and the prevention of recurrence.

What is the role of conservative management?

In recent years there has been a move towards a more conservative approach to management, based on the principle that intrapleural air does not necessarily require a therapeutic intervention, and that management depends on the clinical symptoms and not on the size of the pneumothorax [6, 93]. This conservative approach may be appropriate as tension pneumothorax from a PSP is extremely rare [10, 70]. In selected patients with minimal or no symptoms and good access to medical care in case of deterioration, observation alone may be appropriate.

Within the current British Thoracic Society (BTS) guidelines (from 2010), there is a significant emphasis on a conservative approach to treatment [6] with management predominantly based on clinical symptoms. In contrast, the American College of Chest Physicians (ACCP) Delphi consensus statement (from 2001) recommended a more aggressive approach, with intercostal drain placement recommended in any pneumothorax larger than 20% of the hemithorax, irrespective of the symptoms [21].

Percutaneous needle aspiration or thoracic drain?

Removal of air from the pleural space can be achieved with needle aspiration or chest drain insertion. BTS and ACCP guidelines differ in their view of the utility of needle aspiration, with BTS guidelines suggesting aspiration as an initial intervention in patients with a large or symptomatic primary pneumothorax and ACCP guidelines not suggesting this approach for any patients. Randomised trials published from 1994 onwards are summarised in table 2, with data on the success of aspiration and chest drain insertion.

From this table, the evidence suggests that needle aspiration is effective for the initial management of spontaneous pneumothorax. Following aspiration, patients may be discharged, avoiding hospital admission, although insertion of a small-bore chest tube attached to a Heimlich valve may yield similar results [99, 100]. It should be noted that failure with aspiration occurs at a frequency of 25–50% in PSP [9, 101] and that after a failed aspiration there is no evidence to support a second aspiration over chest drain insertion.

Small- or large-bore chest tubes?

In a retrospective Danish study, smaller bore (11–13 French) tubes seemed to perform better than larger drains (20–28 French) with regard to short-term outcomes [102]. This finding was also noted in two non-randomised studies in young adolescents, in whom small-bore pigtail catheters were found to be as effective as large-bore catheters [103, 104]. Two prospective French studies have shown that ambulatory

TABLE 2 Randomised studies of aspiration *versus* thoracic drainage for initial treatment of spontaneous pneumothorax

First author [ref.]	Year	Patients n	Outcome	Aspiration	Chest drain	Difference
HARVEY [94]	1994	73	Success	80	100	ND
			Hospital stay days	3.2	5.3	p=0.005
			Recurrence at 1 year	17	29	NS
ANDRIVET [95]	1995	61	Success	67	93	p=0.01
			Hospital stay days	7	7	NS
			Recurrence at 3 months	14	29	NS
NOPPEN [96]	2002	60	Immediate success	59	64	NS
			Admissions	52	100	p<0.0001
			Success at 1 week	93	85	NS
			Recurrence at 1 year	26	27	NS
AYED [97]	2006	137	Immediate success	62	68	NS
			Success at 1 week	89	88	NS
			Recurrence at 1 year	22	24	NS
PARLAK [#] [98]	2012	56	Immediate success	68	81	NS
			Success at 2 weeks	100	100	NS
			Recurrence at 1 year	4	13	NS

Data are presented as percentages, unless otherwise stated. ND: not done; NS: nonsignificant. #: includes traumatic pneumothorax.

management of a first episode of PSP with a small-bore drain and a one-way valve is a reasonable alternative to manual aspiration or chest tube drainage and results in significant reductions in overall hospital costs [7, 104]. Additionally, a retrospective study of 55 patients treated with small-bore chest drains connected to Heimlich valves found them to be an effective treatment of PSP [105].

Suction or no suction?

There are few data regarding the utility of applying suction to chest tubes in PSP. Lung re-expansion is achieved in up to 70% of patients with chest tube drainage alone by day 3 without suction [7, 104]. Expert opinion suggests there is no role for the immediate use of suction in all cases [6]; however, a small proportion of patients may benefit from the application of suction in the case of ongoing air leak, where apposition of lung may be achieved through its use. Prolonged use of suction may result in a delay to definitive management, which is associated with poorer clinical outcomes [106]. The use of a digital suction device, capable of quantifying air leak, has been demonstrated to reduce duration of drainage as well as the duration and cost of hospitalisation in patients with an air leak after spontaneous pneumothorax [107].

Recurrence prevention and indications for definitive treatment

In the first episode of PSP, the precise role of invasive treatment to evacuate air and prevent recurrence of spontaneous pneumothorax is a hotly debated topic and no randomised evidence is available [108, 109]. Recently, CHEN *et al.* [4] randomised 214 patients with a first episode of PSP (size >2 cm) to pigtail catheter drainage alone or to catheter drainage followed by pleurodesis with 300 mg of minocycline. There were no specific complications related to either procedure. After a 1-year follow-up period, recurrent pneumothorax occurred in 49.1% of patients in the control group compared with 29.2% in the minocycline group ($p=0.003$). The authors concluded that minocycline pleurodesis is safe and effective and should become the preferred treatment for PSP [4]. However, the 49% 1-year recurrence rate in the control arm is considerably greater than that seen in previous literature in this area and minocycline is not universally available. This study alone is therefore not adequate to change practice until the results are replicated in further studies [13].

In summary, the decision to evacuate air from pleural space is usually determined primarily by the patients' symptoms or wishes, secondarily by their ability to carry out their normal daily activities, and lastly by the size of the pneumothorax. The potential risks of pleural intervention are taken into consideration in making management decisions.

Air travel

Recommendations for air travel passengers after pneumothorax are largely based on anecdotal case reports [110, 111]. A pneumothorax, especially an undrained pneumothorax, is however an absolute contraindication to commercial air travel [112]. Definitive treatment reduces the risk of recurrence and makes air travel safer [110]; however, an individual clinical decision is usually made by the treating clinician, taking into account both airline policy and details of relevant insurance.

Management of persistent or recurrent primary spontaneous pneumothorax

The management of persistent or recurrent PSP continues to be debated [108, 113], partly because of the lack of well-conducted randomised controlled studies in this area. However, there is general agreement that an attempt at definitive treatment should be offered to patients with recurrent or persistent PSP and that this treatment should be cost-effective and based on the best scientific evidence [6, 21].

Indications

The indications for definitive treatment of PSP are summarised in table 3. In recurrent PSP, definitive treatment is offered as soon as practical. A chest tube may be avoided except in clinically unstable patients as a bridge to definitive treatment. In persistent PSP with ongoing air leak longer than 3–5 days, therapeutic options are discussed with the patient. The likelihood of resolution of the air leak and the risks and benefits of prolonged drainage or intervention are considered when making management decisions [106, 114].

TABLE 3 Indications for definitive management of primary spontaneous pneumothorax (PSP)

Second episode of PSP
Persisting air leak >3–5 days
Haemopneumothorax
Bilateral pneumothorax
Professions at risk (aircraft personnel, divers)

Pleural procedures: pleurodesis

Pleurodesis aims to achieve pleural symphysis and prevent recurrence of pneumothorax. It can be performed by instilling a chemical irritant (chemical pleurodesis), by performing mechanical abrasion (mechanical pleurodesis) or with parietal pleurectomy (table 4). Currently, talc is the most commonly used agent in Europe.

Talc is administered as poudrage by thoracoscopy. In Europe the technique of talc poudrage is a very old, simple and cheap procedure performed under visual control by medical thoracoscopy and local anaesthesia [116, 124]. It is also at present administered during video-assisted thoracic surgery (VATS) with an excellent and similar success rate [118, 125]. Direct visualisation of poudrage allows a diffuse spreading of talc throughout the pleural cavity. The long-term success rate after simple thoracoscopic talc poudrage was 93–97% in a report of 13 published series including 505 patients in the 1980s [116].

Debate about the safety of talc originated from case reports, mainly from the USA and Brazil, which highlighted morbidity and mortality associated with the use of talc [126–130]. Research has since shown general dissemination of talc in animals with ungraded talc [131], which was not seen in a similar study using large particle talc [132]. NAVARRO JIMÉNEZ *et al.* [133] compared a variety of forms of talc originating from 13 countries and showed marked differences in the diameter of talc particles. MASKELL *et al.* [134] later showed in humans that systemic side-effects differed depending on whether large or small particle talc had been used. A recent Canadian study reported respiratory compromise in 14 out of 138 patients after talc poudrage using only American Food and Drug Administration approved talc [135], whereas two large European prospective cohorts demonstrated the safety of talc used in Europe in terms of incidence of acute respiratory distress syndrome [17, 136]. The safety of talc has been further established with the observation that talc poudrage does not alter lung function [117, 118, 125, 137]. Following talc pleurodesis, VATS has been shown to be feasible [138, 139]; however, it is the opinion of some Task Force members that it is more technically demanding [106]. Talc poudrage is very cost-effective and, in fact, more economical than a conservative approach using only chest tube drainage [140]. A European multicentre randomised controlled study compared treatment of PSP with a chest tube alone with simple talc poudrage by medical thoracoscopy and found a higher recurrence rate in the chest tube group than in the talc poudrage group (27% *versus* 5%, respectively), resulting in a reduced total healthcare cost in the poudrage group [115]. Talc poudrage under thoracoscopy is a safe, cheap and very efficient agent for achieving pleurodesis provided graded talc is chosen for pleurodesis [119, 120, 141, 142]. The recurrence rate seen after talc poudrage is comparable to that seen after mechanical pleurodesis [143–145]. Other sclerosing agents given *via* a chest tube have been used for prevention of pneumothorax, and include bleomycin dextrose, glucose 50%, iodine, tetracycline or talc slurry [146]. Tetracycline has also been used but is less efficacious than talc poudrage [116, 147] and is no longer available in many countries [148]. Talc slurry is not used in patients with PSP as these patients are able to tolerate pleurodesis with poudrage, which is more effective [9, 149, 150]. The alternative agents are less well studied and sometimes potentially dangerous [151]. Following minocycline pleurodesis, in patients subsequently requiring surgical

TABLE 4 Recurrence rates after definitive treatment of primary spontaneous pneumothorax

Study	Year	Patients n	Mean follow-up months	Recurrence rate %
Simple talc poudrage under medical thoracoscopy				
TSCHOPP [115]	2002	59	60	5
BOUTIN [116]	1991	505	42	7
EL KHAWAND [117]	1995	142	39	6
GYÖRIK [118]	2007	56	118 [#]	5
Talc poudrage with VATS and surgical treatment of lung lesions				
CARDILLO [119]	2006	861	52.5	1.73
CARDILLO [120]	2000	279	38	1.27
Mechanical abrasion				
GOSSOT [121]	2004	111	36.5	3.6
LANG-LAZDUNSKI [122]	2003	167	93	3
Pleurectomy				
AYED [123]	2003	100	48	2

VATS: video-assisted thoracic surgery. [#]: median.

intervention, only localised pleural symphysis at the site of minocycline instillation has been revealed, questioning the efficacy of any slurry-based procedure [152].

In a recent study of 294 thoroscopic procedures performed in South Korea in patients with PSP, additional pleural abrasion did not decrease the recurrence of pneumothorax after wedge resection of bullae [153]. Pleurectomy is a valid procedure for spontaneous pneumothorax [120, 123, 154]. The main criticism is the complication rate and the difficulty in re-entering the chest; most surgeons perform an apical pleurectomy and abrasion lower down the chest to keep the chest cavity accessible in case another VATS procedure or thoracotomy would be required later in life.

In summary, talc poudrage with graded talc is safe and at present the most cost-effective approach to obtain a diffuse chemical pleurodesis preventing recurrence of PSP [155]. In clinical practice we use 2–4 g of talc (Steritalc F2; Novatech, La Ciotat, France) gently sprayed over the pleural surface by a hand-driven pump under visual control, avoiding contact between the tip of the catheter and the pleural surface. This allows a very diffuse distribution of talc particles (fig. 2) and avoids creating patchy areas of talc deposition. There are however some limitations: in the case of visible rupture of the visceral pleura the patient is referred to surgery for resection of the lung with air leakage.

Lung procedures: VATS versus open thoracotomy

VATS allows less invasive access [156, 157] to the thoracic cavity and represents the surgical treatment of choice. BARKER *et al.* [158] recently published a meta-analysis on the management of PSP by VATS or open thoracotomy. They identified 29 studies (four randomised and 25 non-randomised) and found a four-fold increase in recurrence rate of pneumothorax after VATS in comparison with open thoracotomy. Such a meta-analysis mixing randomised and non-randomised studies and compiling more than 20 years of VATS series is highly questionable [159]. A subsequent analysis did not confirm these findings when looking at randomised trials alone and showed a reduction in analgesia use and shorter hospital stays in patients treated by VATS compared with open thoracotomy [160]. In addition to demonstrating equivalent success rates for VATS compared with open thoracotomy [161–163], randomised controlled trials have demonstrated physiological benefits of VATS over thoracotomy including post-operative spirometry [161] and gas exchange [162]. There is a demonstrable “learning curve” in the use of VATS, which may explain the higher recurrence rates for this technique seen in the earlier reported series [164].

There are many surgical procedures that have been developed over the years (table 5). NAUNHEIM *et al.* [165] showed in a multivariate analysis that failure to excise the lung apex was the only significant predictive factor of recurrence of PSP. In this retrospective study, 101 (90%) out of 113 patients surprisingly benefited from some pleurodesis, either mechanical or chemical. The decision about when to excise blebs or bullae remains a point of discussion. Electro- or cold coagulation remains controversial. Evidence shows that bullectomy is better in terms of recurrence compared with bullae ligation [120, 160]. SAKAMOTO *et al.* [166] showed in a retrospective study that coverage of stapling with absorbable mesh after bullectomy seems to improve the success rate of definitive management of PSP. An endobronchial approach using valves to control localised air leaks might offer a promising future treatment [167].

VATS requires double lumen tube intubation, general anaesthesia and an operating theatre but is much less invasive than thoracotomy and is currently the preferred surgical approach for the treatment of pneumothorax [157].



FIGURE 2 Talc poudrage technique. Talc is gently sprayed by a hand-driven pump under visual control. Avoid using talc from pressurised canisters.

TABLE 5 Surgical procedures for persistent or recurrent primary spontaneous pneumothorax

Strategy	Comment
Routine excision of the apex of the lung	Controversial
Selective excision of blebs or bullae	Controversial as not evidence-based for pulmonologists; general agreement among surgeons
Bullectomy	Controversial but better results than bullae ligation in non-randomised studies
Coverage of staple line with absorbable mesh	To be confirmed
Electro- or cold coagulation of blebs and bullae	Controversial
Endobronchial valves to close persistent air leak	Still anecdotal
Talc poudrage	95% success rate at follow-up; not advisable as sole treatment in cases of significant bullae

POMPEO *et al.* [168] performed a randomised study in 2007 comparing awake VATS (with thoracic epidural analgesia) with conventional general anaesthesia. They were able to demonstrate a significant reduction not only in peri-operative pain score and nursing care, but in length of hospital stay and total costs. Such a new approach is interesting, as many other groups have reported less invasive VATS strategies using small calibre instruments [113, 169] or uniportal access [170–172] to the thoracic cavity.

In summary, VATS is the preferred surgical approach over open thoracotomy. There is no conclusive evidence regarding the management of the lung parenchyma in the prevention of recurrence of PSP but some kind of pleurodesis, either mechanical or using talc poudrage, has to be applied to decrease the risk of recurrence of PSP. We also need more randomised controlled trials of these different strategies, especially well-designed prospective trials addressing the points discussed: the management of the lung parenchyma, the pleurodesis technique and the efficacy of VATS compared with medical thoracoscopy.

Post-procedure pain control

Pain is a common complication following pleurodesis procedures with talc or tetracyclines, despite the use of intrapleural xylocaine injection [4, 173, 174]. Seven centres were involved in a randomised multicentre study comparing talc poudrage with chest tube drainage [115]. Pain, as assessed by visual analogue scale (VAS), was significantly higher in the talc poudrage group. Interestingly, such a difference did not exist on the day of the intervention. When further analysing these results, it was found that three out of the seven centres did not use any opioids at all and did not have any systematic pain control policy. Excluding the patients receiving no opioids, there was no significant difference in reported pain levels.

In summary, it may be that pain after pleurodesis, whatever the technique, is often neglected by clinicians, especially in the days after the intervention. It is important for every institution to have not only a systematic assessment of pain by using VAS, but also a systematic pain control policy. After VATS for PSP, better use of analgesia implemented by nurses could perhaps decrease the incidence of chronic pain, which has been reported in 32–46% of patients [175, 176]. In a non-randomised study of analgesia following VATS, percutaneous thoracic paravertebral catheter and morphine patient-controlled analgesia was the technique associated with lowest levels of post-operative pain, although this difference was not statistically significant [177].

Conclusions and further questions

The exact incidence of PSP is not known. The literature would support initial intervention with simple aspiration in symptomatic individuals at first presentation. As recently shown [7, 104], Heimlich valves may offer a promising and alternative method of ambulatory management in PSP if confirmed in large-scale randomised controlled trials [16]. Definitive treatment with thoroscopic poudrage/pleurectomy is often administered in high-risk groups; however, it is not necessary for most patients at their first presentation, as the majority will not recur during their lifetime. Smoking cessation remains the only reversible risk factor known to reduce the chance of recurrence, although we should not neglect the deleterious role of marijuana smoking as a risk of PSP. Aggressive smoking cessation advice is therefore given to all patients who smoke at the first episode of pneumothorax.

There are several questions that require further research. 1) What is the true incidence of PSP? 2) Are there subgroups with a high risk of recurrence of PSP that warrant definitive treatment after their first presentation? 3) Should all PSP be treated with conservative or ambulatory care? 4) Is there a role for genetic testing and thoracic high-resolution CT scanning in all cases of PSP? 5) What are the relative

benefits of talc poudrage *versus* talc poudrage and bullectomy in recurrence prevention? 6) What is the role of lung parenchyma resection in recurrence prevention of PSP?

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