**Systematic Review**

**Management of Primary Spontaneous Pneumothorax in Flight Crew**

**Abstract:**

Primary spontaneous pneumothorax is a thoracic disorder, characterised by an abnormal collection of air in the pleural space, occurring in the absence of underlying lung disease. In aviation medicine, it is a particular pathology that influences flight crew member's fitness to fly. Occurring in apparently healthy individuals, the severity of symptoms varies depending on the size of the pneumothorax, ranging from moderate chest pain and/or dyspnoea to haemodynamic disorders in tension pneumothorax. A chest X-ray is sufficient for the diagnosis. Treatment options include observation, simple aspiration, chest tube insertion, pleurodesis, thoracoscopy, video-assisted thoracoscopic surgery, and thoracotomy.

After a first episode of pneumothorax, the risk of recurrence varies from 20% to 60%, it increases to 62% after a second episode and to 83% after a third episode. Aeronautical physicians are concerned about in-flight recurrence, as related symptoms are likely to affect the performance of the pilots and may result in an aviation accident. The aeronautical environment subjects the body to stresses, which vary according to the type of aeronautical activity carried out, and which are likely to encourage the recurrence of pneumothorax, the two main stresses are altitude hypobaria and longitudinal accelerations (+Gz). To prevent the recurrence of in-flight pneumothorax, pleurodesis is required for fighter, aerobatic pilots and monopilote, while apical pleurectomy associated with abrasion of the remaining pleura and resection of bullae/blebs is necessary for fighter pilots to recover unrestricted aeronautical fitness. For the other categories of flight personnel, the treatment is similar to that of the general patient.

Keywords: pneumothorax, pneumothorax recurrence, aeromedical fitness

**Introduction:**

 Defined as a thoracic disorder manifested as abnormal collection of air in the pleural space, pneumothorax was first described in 1819 by Laënnec [1], since then, more than 30,000 references have been indexed in Pub Med using the keyword 'pneumothorax' [2]. At the same time, the classification of pneumothorax according to the mechanism of its occurrence has been refined, distinguishing between spontaneous and traumatic mechanisms, and whether the occurrence is primary (without underlying lung disease) or secondary (underlying lung disease). primitif spontaneous pneumothorax  PSP is defined as occurring in patients without a prior known underlying lung disease .[3]

 The distinction between primary, secondary, traumatic and iatrogenic pneumothorax is important in view of the different management strategies required for their treatment. Spontaneous pneumothorax is a cause of aeronautical unfitness in aircrew members, due to the risk of in-flight recurrence and is therefore a flight safety issue [4]. Knowledge of the specific nature of the function and the aeronautical constraints is essential in order to avoid a systematic indication for surgery in all members of the flight crew, or to avoid compromising the aeronautical fitness of some of them by inappropriate treatment.

**Epidemiology:**

Occurring in apparently healthy individuals PSP is a common clinical problem with a reported incidence of 1.2/100,000 per year in women and 7.4-28/100,000 per year in men .The incidence of PSP is thought to be increasing and the recurrence rate has been reported to be 20-60% [­5]. The annual cost of PSP in the United States is estimated at $130 million. [6]

Risk factors include tall-and-thin body shape, maleness [7], a population largely represented among flight crews, but the most important risk factor for PSP is cigarette smoking, which increases the risk up to 20-fold in a dose-dependent manner [8], however smoking cessation is associated with a significant reduction in recurrences [9], cannabis smoking has been also demonstrated to be particularly associated with bullous disease [10]. PSP has also been described as occurring in small epidemics, suggesting the role of changes in atmospheric pressure [11] or pollution [12].

### Pathophysiology

The exact mechanism underlying the occurrence of primary spontaneous pneumothorax remains controversial. Some authors believe that the rupture of subpleural bullae and blebs called emphysema-like changes (ELCs), wich is a parenchymal degeneration resulting in a thin-walled avascular ampulla of the visceral pleural, is the cause of pneumothorax [13]. Bullae formation mechanism is the subject of debate, the degradation of lung elastic fibers, induced by the smoking-related influx of neutrophils and macrophages, is the most common explanation [14,15]. After the formation of bullae, the inflammatory obstruction of the small airways increases alveolar pressure, causing air leak into the lung interstitium. The increase in pressure leads to the rupture of parietal pleural, resulting in pneumothorax [16].

The other mechanism is pleural porosity, the development of fluorescein-enhanced autofluorescence thoracoscopy techniques revealed significant areas of fluorescein leakage on the visceral pleura, even in normal parenchyma [17]. This suggests that the inhaled fluorescein was close to the surface of the lung in regions that otherwise appeared normal on plain white light thoracoscopy. This lends weight to the hypothesis of diffuse pleural porosity [18-21].

**Clinical evaluation of primary spontaneous pneumothorax:**

PSP usually occurs at rest, patients have ipsilateral pleuritic chest pain or acute dyspnea, the chest pain may be mild or severe and described as “sharp” and later as a “steady ache.” Symptoms generally resolve within 24 hours, even in cases where the pneumothorax remains untreated and does not resolve [17].

The physical examination of patients with large pneumothorax (free air occupies more than 15% to 20% area of hemithorax) typically reveals decreased breath sounds on auscultation on the affected side, decreased movement of the chest wall and hyperresonance on percussion, If severe tachycardia, cyanosis or hypotension are present, a tension pneumothorax should be suspected [22]. The results of blood gas analysis typically indicate an increase in the alveolar-arterial difference in oxygen partial pressure and acute respiratory alkalosis. Patients with small pneumothorax (<15 percent of the hemithorax) may have a normal physical examination. The most common physical finding is tachycardia [23].

### Diagnosis:

An upright, frontal, inspiratory and postero anterior chest x-ray is the necessary and sufficient examination to diagnose PSP, it shows a pleural line with or without an air-fluid level, radiographs taken during expiration do not improve the diagnostic yield and have been abandoned [24,25].

Computed tomography (CT) of the chest can be used to identify patients with small pneumothoraces (less than 15% of the hemithorax area), CT can also provide more detailed information to assist with subsequent management, including the number, size and location of bullae/blebs (ipsi- or contra-lateral), the possibility of pleural adhesions, pleural fluid collections and possible underlying lung disease [26].

Transthoracic ultrasound can detect the presence of air in the pleural cavity [27]. Pleural ultrasound is more sensitive than standard chest film for detecting residual pneumothorax after drainage [28]. Although ultrasound is commonly used to assess air and/or fluid effusions in patients with polytrauma or in the intensive care unit, the contribution of routine ultrasound to the positive diagnosis and therapeutic management of PSP has not been clearly established [29].

### Treatment:

The management of pneumothorax focuses on evacuating air from the pleural space and preventing recurrence, there are many treatment options, in the case of a first episode of pneumothorax options include: observation, simple aspiration, chest tube insertion, pleurodesis, thoracoscopy, video-assisted thoracoscopic surgery, and thoracotomy [30-32]. In cases of small pneumothorax (less than 15%), healthy patients or patients with minimal symptoms, can be observed and supplied with oxygen. Oxygen supplementation accelerates the reabsorption of air in the pleural cavity by a factor of four; the risk of recurrence is estimated to be 20% - 60% [23]. For patients with larger pneumothoraces (>15%), simple aspiration using an intravenous or thoracentesis catheter is an effective treatment, as is drainage using a pigtail catheter or chest tube. Simple aspiration is successful in 70 % of cases in moderate-sized primary spontaneous pneumothorax [33]. The success rate of drainage through a chest tube in the treatment of a first pneumothorax is 90 %. However, this rate is reduced to 52 % in cases of a first recurrence and to 15 % in cases of a second recurrence [34]. Aggressive therapies such as chest tube drainage or surgery are indicated for larger pneumothoraces (>30%) and recurrent attacks [35].

In cases of primary spontaneous pneumothorax (PSP) that have failed simple aspiration, pleurodesis has been shown to be superior to conservative treatment. The objective of pleurodesis is to achieve pleural symphysis and prevent the recurrence of pneumothorax, it can be performed chemically (by instilling a chemical irritant), mechanically (by mechanical abrasion) or with parietal pleurectomy, at present, talc is the most frequently used agent in Europe and reported to offer excellent results [4-36].

The surgical management of PSP, through open thoracotomy or [Video-assisted thoracoscopic surgery](https://www.mayoclinic.org/tests-procedures/video-assisted-thoracic-surgery/about/pac-20384922) VATS, is typically indicated in cases of: recurrent ipsilateral pneumothorax, first episode with occupational risk such flight crews or persistent air leakage lasting more than five days, or prior contralateral pneumothorax [23, 37]. The surgical management has two objectives, the first of these and the widely accepted is resection of bullae /blebs or the suturing of apical perforations to treat the underlying abnormality, the second is the creation of a pleural symphysis to prevent recurrence [38, 39]. VATS is the preferred surgical approach over open thoracotomy, with equivalent success rates compared to open thoracotomy, VATS is less invasive, reduces the use of analgesics and shortens hospital stays [40].

### Aeronautical risk associated with Pneumothorax:

In aviation medicine, one of the requirements for a crew member to be declared fit to fly is that there should be no cause of incapacitation in flight that could jeopardise flight safety. A pneumothorax manifesting as severe chest pain, severe dyspnea or even respiratory distress would obviously lead to complete incapacitation, with all the more dangerous consequences when the pilot is alone at the controls of his aircraft. Even a simple chest discomfort or moderate dyspnea is a cause for concern in aviation, as it risks distracting the pilot's attention, which must be faultless, especially in turbulence or during critical phases of flight. If there is no co-pilot to take over the controls, the consequences are potentially serious. For non-pilot flight crew, such as cabin crew (stewards and stewardesses) or flight engineers, the occurrence of in-flight pneumothorax-related symptoms is likely to affect the performance of their duties, but is not a priori likely to result in an aviation accident.

### The aeronautical environment and pneumothorax:

In case of a PSP in a flight crew, aeromedical physician fears an in-flight recurrence. After a first episode of pneumothorax, the risk of recurrence varies from 20 % to 60 % with an average of 30%, most occurring within two years of the first episode [5,41], and particularly within the first year in smokers [10]. This risk increases to 62% after a second episode and to 83% after a third episode [42]. Contralateral recurrence occurs in 5.2% to 14.6% of patients [43].

 The risk of recurrence depends on several factors, none of which is predictive alone. Smoking is a recognized one [9,44, 45], which justifies the recommendation of smoking cessation after spontaneous pneumothorax [46]. Other factors reported in the literature include low body weight, particularly in young men [47].

 This risk could be higher for crew members, as the aeronautical environment is a hostile one, subjecting the body to stresses which vary according to the type of aeronautical activity carried out, and which are likely to encourage the recurrence of pneumothorax. Crew members are subject to frequent variations in atmospheric pressure as part of their aeronautical activity. Several factors may combine to increase their intrathoracic pressure, leading to the rupture of pre-existing bullous systems or air leakage from porous areas. The two main ones are altitude hypobaria and longitudinal accelerations (+Gz).

As altitude increases, barometric pressure decreases. The gases contained in the body’s closed

cavities behave according to Boyle-Mariotte’s law, which states that at constant temperature, the volume of a gas varies inversely with pressure: P×V=constant [48, 49]. Consequently, as barometric

pressure decreases, the volume of gaseous systems increases. At an altitude of 3,000 meters, for

instance, the volume increases by 50% [48].In a commercial airliner, the cabin altitude is not

equivalent to sea level; but at cruising altitude (2,438 meters), the expansion of bullae and blebs volume during flight can cause their rupture, leading to pneumothorax. This risk is amplified in military aircraft, which typically are less pressurized than commercial airliners.

Accelerations are also an important factor in the variation of intrathoracic pressure. In fighter aircraft, the pilot is subjected to a 'load factor' or +Gz acceleration. This multiplies the effects of gravity by a factor equal to the intensity of its application [48-50]. Thus, at an acceleration of +5 Gz, the pilot's weight is multiplied by five and the lung apexes are subjected to an inertial force that stretches them downwards five times more than under the effect of Earth's gravity. This contributes to the rupture of the bullous systems, and consequently to a pneumothorax. In order to improve their tolerance to these accelerations, fighter pilots are trained to perform respiratory and muscular manoeuvres known as anti-G manoeuvres, which increase their intrathoracic pressure and can therefore cause the rupture of the bullous systems. [50]

**Optimum care for flight crews:**

Prevention of recurrence of in-flight pneumothorax includes pleurodesis for fighter or aerobatic pilots. Achieving the strongest possible pleural symphysis is a necessary condition for regaining unrestricted flight fitness; this symphysis must be sufficiently effective that the risk of recurrence is practically zero, even under the effect of acceleration which will pull on this symphysis.

 Among the different techniques, chemical pleurodesis is not considered acceptable for the treatment of crew members due to its high failure rate: 12.9% for minocycline [51], up to 9% for pleural talcation [46], decreasing to 5% when talcation is combined with pneumonectomy [52], which still considered too high in aviation medicine. Mechanical surgical pleurodesis using video thoracoscopy seems to us to be the method of choice in minimizing the risk of postoperative morbidity [53,54], apical pleurectomy associated to abrasion of the remaining pleura and resection of bullae/blebs is required for fighter pilots to allow them to recover unrestrictedly aeronautical fitness, a 15-year serie in the surgical department of the Army Hospital in Paris shows no recurrence of pneumothorax in fighter pilots, allowing them to return to full fitness [53]. For the other categories of flight personnel, the treatment is similar to the general patient.

**Aeromedical fitness management:**

The flight crew represents a selected population that is medically monitored. They are required to meet medical fitness conditions that adhere to regulatory standards, which vary according to crew member category. Despite these variations, the objective remains consistent: to ensure the safety of flights and the transported individuals, as well as the fulfillment of missions. [55]

A pneumothorax can result in temporary unfitness for flight. Once the lung has returned to the chest wall, the patient can be considered fit to fly again. However, it is essential to allow sufficient time for the visceral breach to heal properly, and in case of pleural symphysis, to ensure the solidity of the pleurodesis. If the patient have a bullae or bleb, their presence does not necessarily increase the risk of recurrence [56,57]. However, aeronautical factors can significantly increase this risk during flight. In any case, they can favor the aggravation of a recurrence during flight. [45]

It was decided not to systematically screen for these bullae during the initial medical evaluation: on admission, only a systematic chest x-ray is required by the regulations [58]. However, in the event of spontaneous pneumothorax, a high-resolution thoracic CT is mandatory for flight crew members, as opposed to the recommendations for ordinary patients [45,56]. Regardless of the category of flight crew, the presence of subpleural air bullae/blebs is not acceptable for unrestricted aeronautical fitness, particularly if they are multiple or supracentimetric, unless pleural symphysis is performed. Finally, a functional respiratory examination with measurement of carbon monoxide transfer must be performed at a distance from the pneumothorax or its treatment to demonstrate the absence of repercussion on the respiratory function [45].

 In the case of PSP, it is the restoration of the aptitude of the fighter pilot that poses the mainth problem, as they are exposed to all the aeronautical factors likely to facilitate recurrence (hypobaria, accelerations, "anti-G" maneuvers). After a post-operative period of at least three months, the return to flight is always preceded by a centrifuge test, which tests the efficiency and painlessness of the pleural symphysis under the influence of accelerations, as well as a test in a hypobaric chamber. If the pilot does not wish to undergo the surgery, which is exceptional, "fighter unfitness" is the rule, with conversion to a transport aircraft. Civilian aerobatic pilots, who are subject to the effects of accelerations, and all single pilots without a co-pilot to take control of the aircraft in the event of a recurrence of in-flight pneumothorax, present a particular problem; surgical pleural symphysis is required to restore full flight fitness, the choice of procedure is at the discretion of the surgical team. For all other categories of flight crew, including commercial airliner pilots, the management of pneumothorax does not differ from the general population.

Current standards allow pilots to return to flight six weeks after the lung has returned to the chest wall, even after simple drainage, assuming there are no thoracic CT abnormalities and there is a qualified second pilot on board. Surgical symphysis is required for all flight members from the second episode in case of recurrent pneumothorax. [45.58]

In cases of secondary pneumothorax, the assessment of fitness to fly depends also on the underlying pathology. Traumatic pneumothorax [45], on the other hand, is not associated with the risk of recurrence due to the effraction of the two pleura [3].

**Conclusion**

In the context of aviation medicine, pneumothorax is one of the few pathologies where the decision on fitness to fly is directly linked to treatment, particularly in the case of fighter pilots, aerobatic and monopilotes. It is therefore important to have knowledge of the specificities of the management of PSP in those specialities. This approach helps to prevent unnecessary surgical procedures in certain categories of flight members and, conversely, to avoid any negative repercussions on the professional aptitude of other categories by avoiding surgical symphysis. The appropriate treatment is determined on a case-by-case basis.

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