UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

AD-A240 342

REP

Form Approved
OMB No 0704-0188

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b DECLASSIFICATION / DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) USAFSAM-JA-86-19	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION USAF School of Aerospace Medicine 6b OFFICE SYMBOL (If applicable) USAFSAM/NG	7a NAME OF MONITORING ORGANIZATION
6c ADDRESS (City, State, and ZIP Code) Aerospace Medical Division (AFSC) Brooks Air Force Base, TX 78235-5301	7b ADDRESS (City, State, and ZIP Code)
8a NAME OF FUNDING / SPONSORING ORGANIZATION USAF School of Aerospace Medicine 8b OFFICE SYMBOL (If applicable) USAFSAM/NG	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code) Aerospace Medical Division (AFSC) Brooks Air Force Base, TX 78235-5301	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO: 62202F PROJECT NO: 7755 TASK NO: 27 WORK UNIT ACCESSION NO: 01

11 TITLE (Include Security Classification)
Spontaneous Pneumothorax in the USAF Aircrew Population: A Retrospective Study

12 PERSONAL AUTHOR(S)
Voge, V.M.; Anthracite, R.F.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Interim	FROM 1952 TO 1984	1986 October	11

16 SUPPLEMENTARY NOTATION
Article submitted to Aviation, Space, and Environmental Medicine, 57(10 pt1): 939-949(1986)

17 COSATI CODES		
FIELD	GROUP	SUB-GROUP
06	05	
06	04	

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Spontaneous Pneumothorax(SP), Flight Crews, Dyspnea, Respiratory Diseases, Bilateral Parietal Pleurectomy, Surgery, Chest Pain, Blebs, Bullae, Cysts

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Spontaneous Pneumothorax (SP) is infrequently diagnosed in aircrew personnel. However, once it is diagnosed, aircrew disposition becomes a serious concern. To evaluate this problem, a literature review was conducted to put the disease into proper perspective. A questionnaire was then sent to all aircrew in the United States Air Force waiver file who had suffered SP in order to gain a retrospective view of problems and situations encountered. The following areas were investigated: recurrences height, weight, age, smoking history, initial medical management symptomatology, activity at time of occurrence, relationship to flight duties, treatment given and personal/family history of lung disease. A review of FAA, military, and NASA guidelines regarding personnel with a history of SP was also done. It is concluded that SP is an unrecognized hazard to aircrew personnel. Once an SP has been diagnosed in an individual, he/she should be grounded from further flight duties until either 9 years have elapsed without a recurrence or there has been a bilateral parietal pleurectomy.

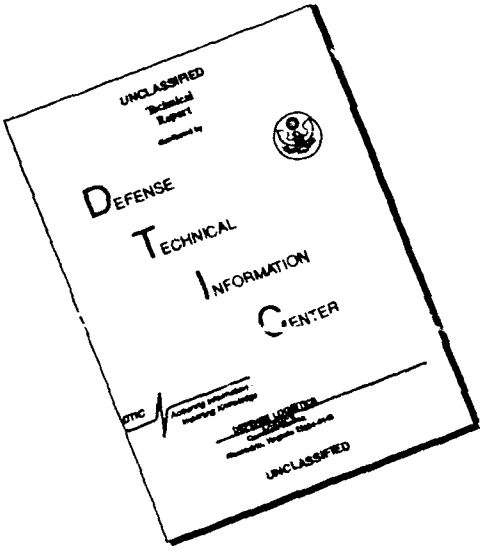
20 DISTRIBUTION / AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	Unclassified

22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code)	22c OFFICE SYMBOL
James R. Hickman, Jr.	(512) 536-2811	USAFSAM/NG

DD Form 1473, JUN 86 *Previous editions are obsolete*

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

Spontaneous Pneumothorax in the USAF Aircrew Population: A Retrospective Study

V. M. VOGE, M.D., M.P.H., and R. ANTHRACITE, M.D.

Naval Hospital, Corpus Christi, Texas

VOGE VM, ANTHRACITE R. *Spontaneous pneumothorax in the USAF aircrew population: a retrospective study.* Aviat. Space Environ. Med. 1986; 57:939–49.

Spontaneous pneumothorax (SP) is infrequently diagnosed in aircrew personnel. However, once it is diagnosed, aircrew disposition becomes a serious concern. To evaluate this problem, a literature review was conducted to put the disease into proper perspective. A questionnaire was then sent to all aircrew in the United States Air Force waiver file who had suffered SP in order to gain a retrospective view of problems and situations encountered. The following areas were investigated: recurrences, height, weight, age, smoking history, initial medical management, symptomatology, activity at time of occurrence, relationship to flight duties, treatment given and personal/family history of lung disease. A review of FAA, military, and NASA guidelines regarding personnel with a history of SP was also done. It is concluded that SP is an unrecognized hazard to aircrew personnel. Once an SP has been diagnosed in an individual, he/she should be grounded from further flight duties until either 9 years have elapsed without a recurrence or there has been a bilateral parietal pleurectomy.

SPONTANEOUS PNEUMOTHORAX (SP) is an entity of extreme importance in the aerospace community. The condition may bring about sudden incapacitation when least expected.

SP is a relatively common entity in tall, thin, young, healthy males (17,43,70,90). The incidence rate ranges from 2–46 per 100,000 (18,48,70,77,112,113) and is felt to be increasing (17,27,32). This rate has been found to be higher in the military population, primarily because that population is composed of young, healthy males (4, 27,99). About 1 out of every 500 young men may have a history of SP (93). The actual incidence is probably higher than that reported since not all physicians report their cases of SP and, if symptoms are mild, a patient may not consult a physician (28).

The frequency of SP peaks at two different age groups—one large peak at age 20–29 years and a smaller peak at age 50–70 years (4,15,17,20,30,35,44, 46,49,62,63,70,74,88,90,91,95,97,105). The younger age group is comprised of young, healthy males usually assumed to have suffered rupture of an apical subpleural bleb or bulla (3,6,9,12,14,17,20,24,25,27,30,36,48,62, 63,64,70,77,83,91,95,109). There commonly is no prior history of disease, pulmonary or otherwise (62, 70) and occasionally no blebs are found at surgery (70). Apical bullae or blebs are quite common in the general population (50) and are usually bilateral (24,25,26,33, 39,48,57,77,95,113). Some feel that young, tall, thin males may have an "heritable" defect that is exacerbated by the greater vertical length of the chest, making the apex more vulnerable to gravitational stresses (26,107). SP is usually due to an underlying disease process in the older population (4,17,99). This older age group will not be considered further.

SP appears to have a predilection for males, affecting up to 5–10 times as many males as females (12,20,24,26, 46,55,60,70,91,95,105). Family history of pulmonary problems or SP does not seem to be an indicator for the subsequent risk of SP, although a familial incidence of 2% has been reported (70,105). Activity level at the time of SP does not seem to affect the incidence rate of SP. About 75% of SPs occur during light or sedentary activity or during sleep and are apparently unrelated to stress (16,17,18,25,28,39,40,56,70,75,95,

This manuscript was received for review in June 1985 and was accepted for publication in August 1985.

CDR V. M. Voge, MC, USN, is Head, Aviation Medicine/Military Medicine Department of the Naval Hospital at Corpus Christi, TX. Send reprint requests to CDR Voge at Box 729, Odem, TX 78370.

The opinions herein are those of the authors and not the USAF.

105,112). Some series relate a greater incidence of SP in smokers: up to 88% of those suffering SP also smoke (14,20,25,80). Other studies disagree (112). There is no predilection as to which lung is affected (17,19,54,61,70,84,91,95,105,112). About 2% of all SPs are bilateral simultaneously (23,30,46, 55,70,91,95). Such a condition, even without associated pulmonary pathology, is potentially fatal (5,21,62,112). The mortality rate from SP, overall, is less than 1% (18, 105).

Symptomatology of SP usually consists of a nonproductive cough, pleuritic-type chest pain, and dyspnea, which may or may not be persistent (14,17,18, 25,35,70,75,94,95,113). The symptoms may be of sudden onset, severe and life-threatening, with severe respiratory and cardiac insufficiency, in up to 10% of the cases, (14,32,70,112). About 7% of SP patients do not even notice symptoms which might alert them to the possibility of an SP (17,18,70). Young individuals, even with the total collapse of a lung, may not appear severely ill (46). Symptoms are more likely to be present if the SP is bilateral (46).

On physical examination, the patient may appear to be in no distress or may be in acute respiratory distress (75,113). There is usually no elevation in body temperature or of the erythrocyte sedimentation rate (70).

The diagnosis of SP is confirmed by chest X-ray (38). There is no radiological evidence of pulmonary disease in about 80% of cases, and no evidence of a previous SP in well over half of the cases (12,17,30). Patients are most frequently misdiagnosed as having the flu, an acute URI, a "circulatory disturbance," or a myocardial infarction (46).

The treatment of SP may be conservative or surgical. Conservative therapy consists of bed rest and/or needle aspiration (thoracocentesis) and/or a chest tube. Surgical treatment consists of chemical or mechanical pleurodesis, parietal or complete parietal pleurectomy, and/or surgical excision of bullae and blebs (62). There is no consensus as to which therapy is the best for nonaviation personnel, in spite of voluminous literature on the subject (99,102).

Conservative therapy is unacceptable in the aviation community because of the high SP recurrence rate after such treatment (27,42,62,113).

Surgery for SP is usually indicated when the lung fails to reexpand after 3–10 d, recurrent SP, tension pneumothorax, chronic unexpanded pneumothorax, hemopneumothorax that fails to respond to aspiration, bilateral pneumothorax, fistula, or the presence of thin-walled, air-containing cysts on chest X-ray (11, 14,20,23,24,65,66,70,73,80,83,99,102,112,113). The goal at operation should be to remove the causative lesion and/or to obliterate the pleural space by the simplest possible technique (20,63). Surgery may be performed through a large thoracotomy or median sternotomy (bilateral bleb excision and/or bilateral parietal pleurectomy) or a small lateral incision in the fifth or sixth intercostal space (24,77,82). It is generally agreed that surgical symphysis does not interfere with lung function (27).

Pleurodesis is frequently used in recurrent SP (98, 99). Pleurodesis may be mechanical or chemical. Both methods have their advocates and detractors. Pleurodesis causes intrathoracic inflammation to the extent that the lung fuses to the thoracic wall obliterating the pleural space (55). Many authors prefer mechanical pleurodesis to chemical pleurodesis because the former is less painful and "more effective" (20,52,91,99,105, 112). Others feel that chemical pleurodesis—the insufflation of a foreign substance into the pleural cavity—is the most successful method of treatment (20,30,42). In spite of the multitude of chemical agents used, none has proven satisfactory (1,2,7,8,13,18,20,30,35,42,47,53, 55,69,70,71,79,90,92,97,98,102,104,108). The major reasons for chemical pleurodesis' unsatisfactory results are that adhesions are either inadequate or produced on the diaphragmatic and/or mediastinal surfaces where they are of little value (4,29,41). There may also be increased postoperative morbidity (8,17,24,29,30,36, 42,44,54,58,70,79,102,108). In spite of its morbidity, chemical pleurodesis cannot be guaranteed to prevent further recurrences (10).

Many thoracic centers have abandoned pleurodesis in favor of parietal pleurectomy because of pleurodesis' high recurrence rate (97). The recurrence rate after parietal pleurectomy is 0–1% (4,20,30,70,90,95). It would appear that thoracotomy with resection or obliteration of blebs and parietal pleurectomy provide the best protection against both persistent air leaks and recurrences (20,91,95). Simultaneous bilateral thoracotomies are a major insult to any patient but, since the contralateral recurrence rate is so high, it is only prudent to repair both sides simultaneously (6,77) or separately.

Parietal pleurectomy is felt by many to be the treatment of choice in persistent or recurrent SP for those who are sufficiently fit to undergo a surgical procedure (4,35,42,65,91,95,96,112). Parietal pleurectomy creates a uniform inflammatory surface with secondary adhesions of the lung to the endothoracic fascia (20). This procedure is felt to be the best chance for a permanent cure and that it should be performed early (4,77,95). Even though thoractomy and pleurectomy are major surgical procedures, the morbidity and mortality are no greater than that for chemical pleurodesis (42,95). The complication rate is extremely low (4%). Some studies report no complications, to include recurrences or deaths (4,20, 29,30,95,96). Postoperative pulmonary function tests have been routinely reported as being normal even after bilateral procedures (3,4,20,29,30,96). Parietal pleurectomy is not a radical procedure since there is little additional trauma compared to mechanical or chemical pleurodesis. The pleurectomy may be partial or complete (4,20,95).

The most common and important complication of SP, recurrence, needs special consideration (14,29,30, 46,55,91,97,106). Most patients who experience SP will have a recurrence (71). The time between recurrences is usually less than 1 year, (17,39,48,62) and two-thirds of recurrences will appear within the first 2 years after the initial occurrence. The average interval

between SPs is about 2.3–3.1 years (17,18,42,74). However, the interval for first recurrence can be as long as 10–21 years (17,74). The reported recurrence rates very widely. This wide variance is usually due to a) length of follow-up, b) whether the SPs are suspected or radiologically proven, c) interpretation of interval history, d) inclusion or noninclusion of contralateral episodes, e) noninclusion of previous episodes before treatment—an "initial episode" may not be a patient's first SP, f) type of therapy given for the SP, and g) size and composition of the study group (25,49). Each recurrence significantly increases the chances of another episode (25,49,62). First recurrence rates with conservative therapy vary from 10–60% (17,18,24,29,30,34,37,41,45,49,51,57,59,62,70,73,80,85,87,89,90,95,97,101,102,105), and tend to be high because the blebs that originally caused the SP are still present. The frequency of second recurrence after conservative therapy is 17–80% (14,42,73) and for third and fourth SP is 80–100% (14,18,24,30,73). Of patients with SP, 10–20% will develop SP in the contralateral side (17,30,61,73,80,90,97) and 2–3% will experience a simultaneous bilateral SP (30,45). It is generally agreed that patients with one or more recurrent SPs should have some form of surgical treatment since recurrence risk is so high (20,32,62,76). Chemical or mechanical pleurodesis have high recurrence rates varying from 0–30% (17,20,30,42).

Aeromedical Aspects

SP may be innocuous at ground level. It is neither common nor important statistically for the ground armed forces. The problem is more serious for aircrew members exposed to the added hazards and risks of flying, with the possibility of incapacitation and subsequent inability to control the aircraft (25, 27,28,68). SP can cause distraction because of chest pain, dyspnea, and hypoxia (28,42,68). In flight it can cause an aviator to relinquish his duties or to abort the mission, or can cause a serious mishap or a major disaster. In single-seat aircraft, SP may cause loss of life or loss of the aircraft. The cause of the mishap may be erroneously labeled as "unexplained" or due to "human error." Therefore, one should take a conservative attitude when grounding aviators with blebs, bullae, cysts, or a history of SP (27,28,39).

The etiology of SP in aircrew personnel appears to be similar to that of the general population, the predisposing pathology being more important than environmental stresses (28,39,94). Others feel operational flight may induce SP in an individual with preexisting pulmonary malformations, e.g. blebs. This is of concern since the individual with malformations is exposed, over the years, to high G, rapid decompressions, pure oxygen breathing with forced expiration, increased gravitational forces, and/or chest restriction due to anti-G suits (27, 86,111). The concern is that, at altitude, the involved lung may collapse completely and/or form a tension pneumothorax (27,42). If one continues to fly with a SP, further compression of the lung with mediastinal shift and/or sudden death may occur. Air embolism is also felt to be a danger (39).

The onset of SP is more likely during nonflying hours (28,39,94). There have been relatively few cases reported during flight (12%) or in low-pressure chambers (LPC) (4,17,25,28,34,39,48,51,102).

Conservative therapy is not appropriate for aircrew personnel because of the known high recurrence rate of SP and its attendant dangers at altitude (27,62,113). Some authors feel surgical correction is the treatment of choice, even in those who have not experienced an SP but who have significant bleb formation with expansion at altitude (39).

Return to flight status after an SP should be based on a thorough aeromedical evaluation and examination (28). The civil aviation and military regulations governing the treatment/disposition of an aircrewman with an initial episode of SP vary greatly (31,67,72, 100,103).

METHOD

A retrospective questionnaire study was carried out by reviewing the cases of 147 aircrewmen with a history of SP in the USAF Waiver File at the U.S. Air Force School of Aerospace Medicine. Eighteen-item questionnaires were sent to each involved aircrewman to ascertain the peculiarities of his experience.

We conducted a literature search for general information, signs, symptoms, incidence, complications, treatment modalities, and recurrence rates of SP. From this we hoped to determine the most reliable therapeutic modality to ensure nonrecurrence in the aircrew population. In conjunction with this, we reviewed the U.S. Navy, U.S. Air Force, U.S. Army, NASA, and the FAA Regulations concerning the disposition of aircrewmen suffering SP (Table I).

RESULTS

Of the 147 individuals identified in the USAF Waiver File as having suffered SP, 2 were excluded from the survey for administrative reasons, 2 were deceased, and 1 refused to answer the questionnaire, leaving a possible 142. Of these, 4 were excluded because they suffered a traumatic pneumothorax rather than a spontaneous pneumothorax. Of the eligible 138 aircrewmen, 112 responded to the questionnaire for an 81% return rate. Of these aircrewmen, 41% are still actively flying. The follow-up time varied from less than 1–32 years with an average follow-up time of 10 years.

Recurrence

There were 151 episodes of SP in the 112 aircrew members responding. Of these 112, 28% experienced a first recurrence, 23% of this 28% experienced a second recurrence, and 14% of this 23% experienced a third recurrence for a total recurrence rate of 35%. No one in our retrospective study reported more than four SPs. The average age of first occurrence was 27 years, at first recurrence 31 years, at second recurrence 34 years, and at third recurrence 36 years.

The time interval between initial SP and recurrence was skewed toward somewhat longer intervals compared to other series (17,18,39,42,48,62,74). Of all recurrences, 56% occurred within 2 years, 77% within 6 years, and 95% within 9 years of the preceding SP.

TABLE I. RULES AND REGULATIONS GOVERNING SPONTANEOUS PNEUMOTHORAX.

	Entry Into Flight Program	Retention In Flight Program
Federal Aviation Administration (31)	Spontaneous pneumothorax is disqualifying for aviation duty -unless resolved radiographically and no underlying disease is present	Spontaneous pneumothorax is disqualifying for aviation duty -unless resolved radiographically and no underlying disease is present
U.S. Navy (67)	Spontaneous pneumothorax is disqualifying for aviation duty -if present within 3 years of examination; -unless surgically corrected if no significant residual disease or deformity exists and pulmonary function tests are normal	-if reccurrent by history
U.S. Army (100)	Spontaneous pneumothorax is disqualifying for aviation duty -if present within 3 years of examination -unless surgically corrected if not significant residual disease or deformity exists and pulmonary function tests are normal	Same
U.S. Air Force (103)	Spontaneous pneumothorax is disqualifying for aviation duty -by history	-by history, except a single episode may be waived if complete recovery with full lung expansion, normal pulmonary function tests, and no underlying disease -unless successful pleurodesis performed and normal pulmonary function tests, after 6 months of observation (requires hypobaric chamber evaluation)
NASA (72)	Spontaneous pneumothorax is disqualifying for aerospace duty -by history -unless surgically corrected and without recurrence for 5 years	-unless surgically corrected without recurrence for six months

The follow-up interval after an initial SP at which the probability of recurrence becomes negligible is about 9 years. The mean interval between SPs was about 3 years in all cases.

Height, Weight, Age

The average height of our study group was 71.7 in and the average height of those currently actively flying is 73.4 in. The average weight of all respondents was 173.6 lbs (Fig. 1). The average age was 43.4 years overall and 40 years for those still actively flying (Fig. 2). Of all respondents, 41% were under 40 years of age, and 48% of all aircrew in our population currently flying are under 40 years of age.

Smoking

Of the aircrewmen in our series, 79% have a positive smoking history, with an overall average of 30.75 pack-

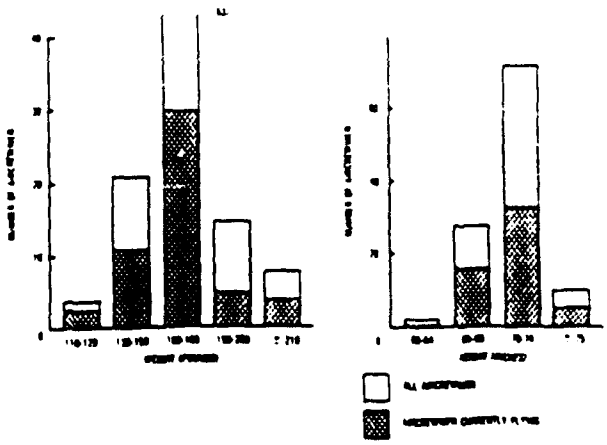


Fig. 1. Height and weight of all aircrew and those currently flying.

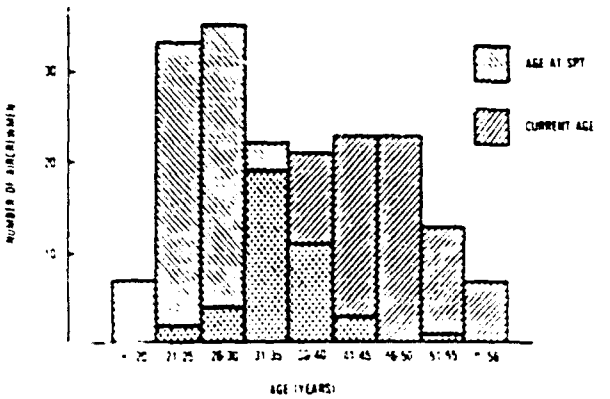


Fig. 2. Age at occurrence of SPT and current age of population.

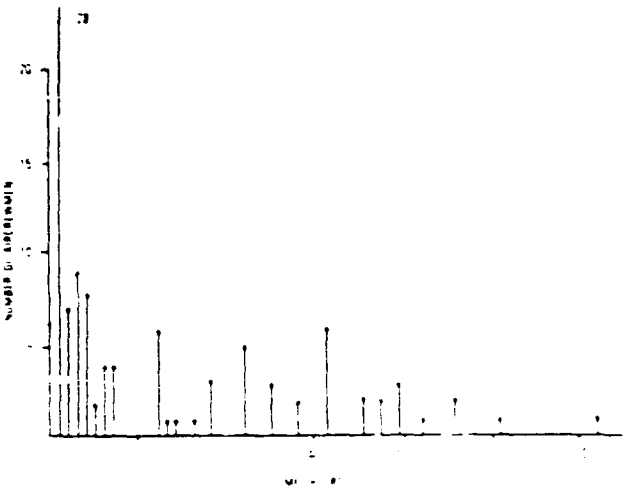


Fig. 3. Time delay in seeking medical attention after experiencing SPT.

years. There is no direct relationship between pack-years per individual and number of recurrences. We did not obtain data on whether the aircrewman is a current smoker or not. Of aircrewmen under 40 in our study group, 65% are nonsmokers. However, only 31% of current flyers under 40 years of age in our group are nonsmokers (Table II).

Initial Treatment

Only 82% of patients with SP were seen by a flight surgeon. The delay in seeking medical attention varied from 0–336 h with a mean of 24.6 h, a median of 4 h, and a mode of 0.5 h (Fig. 3). Of the patients, 32% waited 1 h or less and 54% waited 4 h or less to see a physician; 21% waited more than 24 h to see a physician. All but one of those with a second or third recurrence sought medical attention within 3 h of occurrence, the latter waiting 12 h. The reasons given for delaying medical treatment were fear of grounding, distance from or availability of medical services, and/or the lack of severity of symptoms.

Symptoms

The most frequently reported symptoms were pain (89%), dyspnea (61%), difficulty moving right or left arm (6%), fatigue (6%), near loss of consciousness (6%), and URI-type symptoms (6%). Other symptoms mentioned were sore throat, cyanosis, heartburn, cough, "thought was having an MI," nausea, audible heart beat, dizziness, increased pulse rate, audible pleural "knock," difficulty running or jogging, choking, diaphoresis, weakness, cramps, fainting, paleness, fear, "didn't feel like smoking," and tachypnea (Table III). The pain had many different characteristics, such as knife-like, dart-like, similar to a "pulled muscle," cramp-like, like a "steel band" on chest; pain on bending over, moving, or with exertion; and in various locations such as shoulder blades, shoulder, back upper chest, under rib cage, in arm, etc. Some patients experienced no pain. Other individuals experienced pain so severe it caused them to double over and almost lose consciousness. Two individuals claimed no symptomatology, stating that their SP was discovered on a routine examination.

Activity

There was no relationship between activity level and the occurrence of SP—24% were sleeping, 33% were participating in minimal effort activities (sitting at desk, eating, etc), 28% were involved in moderate effort activities (getting in and out of car, walking, etc), and 11% were involved in great effort activities (racketball, jogging, tennis, etc). Five percent of the individuals could not remember what they were doing at the time of symptom occurrence.

Flight Relationship

Of those answering the questionnaire, 70% have flown military aircraft within the last 4 years (1980–83) (Fig. 4). Only 3% last flew prior to 1970. Thirty-seven percent of aircrewmen admitted to having flown within the 24 hours before or after their SP. Of this 37%, 63% had been flying "straight and level" profiles and 37% high-G or rapid-change-in-altitude profiles. Of those

TABLE II. SMOKING HISTORY OF AIRCREWMEMBERS WITH SP.

56% of non-smokers are currently flying
24% of current flyers are non-smokers
22% of all flyers are non-smokers
17% of former flyers are non-smokers
65% of those under 40 years of age are non-smokers and 41% of aircrewmembers are under 40 years of age
31% of current flyers under 40 years of age are non-smokers

TABLE III. REPORTED SYMPTOMATOLOGY WITH SPONTANEOUS PNEUMOTHORAX (n = 112).

SYMPTOM	NUMBER	(%)	SYMPTOM	NUMBER	(%)
Pain	100	(89)	tachycardia	2	(2)
Shortness of breath	68	(61)	choking	2	(2)
Difficulty moving arm or leg	7	(6)	pleural "knock" sensation of "something moving in chest cavity"	2	(2)
Near loss of consciousness	6	(5)	diaphoresis	2	(2)
Tired/fatigue	6	(5)	difficulty jogging/ running	2	(2)
URI symptoms	6	(5)	weakness	1	(1)
Cyanosis	5	(4)	cramps	1	(1)
Sore throat	3	(3)	fainting	1	(1)
Loss of consciousness	3	(3)	paleness	1	(1)
Nausea	3	(3)	fear	1	(1)
"Heartburn"	3	(3)	"didn't feel like smoking"	1	(1)
Cough	3	(3)	tachypnea	1	(1)
Thought was having M.I.	2	(2)			
Audible heart beat	2	(2)			
Dizziness	2	(2)			

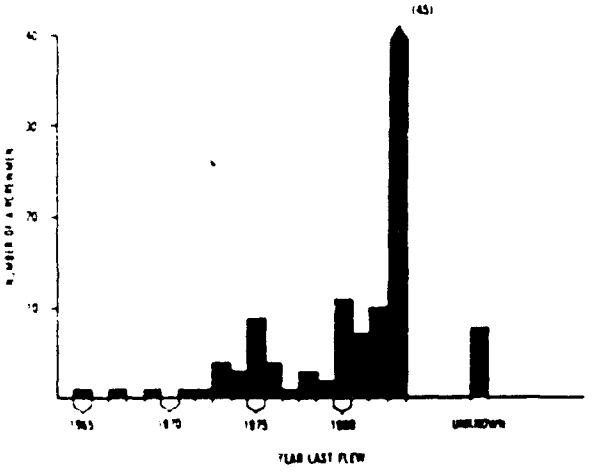


Fig. 4. Last year of active-duty flying for each aircrewman.

who suffered an SP within 24 h of flying, 30% suffered it during flight. Several individuals elected to fly immediately after the appearance of symptomatology. Seven percent of the aircrew had been in a low-pressure chamber (LPC) within 24 h of their SP. All had experienced rapid decompression during their LPC flight, and 86% of these experienced their SP during the LPC flight. Of these, 80% experienced their SP during the rapid decompression phase.

The question "Could the symptoms have compromised flight safety had they occurred in the air?" was answered affirmatively in 28 cases (19%) and "maybe" in 27 (18%). Thus, 37% of aircrewmen reported that the symptoms would or could have compromised flight safety had they occurred in the cockpit environment. The question "Were you incapacitated by the symptoms?" was answered positively by 27 (18%) and "maybe" by 7 (5%) of the aircrewmen, for a total of 23%. The reported severity of symptoms frequently did not coincide with the aircrewmembers' evaluations of the symptoms' effect on flight safety or incapacitation. (Table IV).

Treatment

While 67% of patients were treated initially with a chest tube alone or in combination with other procedures, 19% were given "no treatment" (bedrest). After the first recurrence, only four patients were treated surgically while three individuals were given "no treatment" (bedrest). After the second recurrence, 71% were treated surgically. After the third recurrence, 100% had surgery (Table V). Only 35% of the aircrewmembers still flying have been surgically corrected. All but three were surgically corrected after one or more recurrences of SP. The treatment modalities were reported by the patients and we cannot verify them.

Family and Personal History

There is no correlation between experiencing an SP and a personal history of lung disease. Immediate blood relatives seem to have a higher incidence of lung disease and SP compared to the general population, however. This has not been reported previously.

Current Aircrew Standards

All agencies reviewed (civilian and military) have unique dispositions for aircrew members who have suffered an SP. Grounding periods vary from none for a single episode to 5 years following surgical correction (Table I). NASA (72) has the most stringent requirements, dictating a 5-year grounding period after surgical correction after an initial SP episode. The FAA (31) requires only that the SP be resolved radiologically and that there be "no underlying disease." The three military services (67,100,103) dictate that SP is disqualifying for aviation duty if the individual is an applicant for a flight program. However, once in the

TABLE IV. AIRCREWMEMBERS' RATINGS OF REPORTED SP SYMPTOMATOLOGY AS TO WHETHER SYMPTOMS AFFECTED FLIGHT SAFETY OR CAUSED INCAPACITATION.

	Flt. Safety	Incapacitation
Left shoulder and arm pain; thought he was having an M.I.	no	no
Deep chest discomfort, aching pain, positional mild dyspnea	no	no
Pain in left lung; difficulty breathing; left arm pain; dizziness	yes	no
Left-sided pain; could not take full breath; crushing sensation	no	no
Extreme pain in upper chest; "thought I was having an M.I."	maybe	no
Cold sweat, pale, shortness of breath, "100% oxygen and one good lung would be sufficient to fly"	[illegible]	no
Sharp pain in collar bone; could only breathe with back rigid	maybe	no
Rapid and shallow breathing with sharp pain on deep inspiration in chest and right shoulder blade	no	no
Sharp chest pain; slight weakness in left arm, cyanosis, fatigue	no	no
Sharp pain in lower left back, not severe enough to immobilize, trouble straightening up	N/A	no
Pain left chest, shortness of breath, very uncomfortable; "thinking it was indigestion. I just wanted to get on the ground"	no	no
Extreme pain in sternum and became very tired some shortness of breath; difficulty in moving right arm (limited movement)	yes	no
Sharp burning pain in chest; "I felt no impairment of thought or coordination"	no	no
Chest pain, shortness of breath, "I had chest pain and could not take a deep breath, but I was able to move about, never lost consciousness or felt like was going to lose consciousness"	no	no

TABLE V. REPORTED TREATMENTS OF SPONTANEOUS PNEUMOTHORACES OF THOSE WHO RESPONDED (n = 151)

TREATMENT	1st OCCURRENCE	2nd OCCURRENCE	3rd OCCURRENCE	4th OCCURRENCE
Chest tube	89	3	-	-
Surgery	4	18	8	1
Oxygen	1	-	-	-
Needle aspiration	7	1	-	-
None	21	3	2	-
Chest tube plus surgery	5	2	-	-
Chest tube plus oxygen	9	1	-	-
Chest tube plus needle aspiration	1	-	-	-
Needle aspiration plus oxygen	3	-	-	-
Needle aspiration plus surgery	-	1	-	-
Chest tube, oxygen, and surgery	-	1	-	-

program, there are no firm guidelines regarding aviation duty after an SP.

DISCUSSION

SP may be a serious, incapacitating malady in the aviation environment. We found USAF recurrence rates were lower than those reported for the general population (17,18,24,29,30,34,37,41,45,49,51,57,59,62,70,73,80,85,87,89,90,95,97,101,102,105). Several reasons for this may be: a) those who did not respond to the questionnaire may be a unique group, b) the aircrew population may underreport symptoms, the number of

occurrences, or the number of recurrences, c) some of the aviators had a very short follow-up period of only 1 year, and d) conclusions drawn from such a small study group are uncertain. The length of time between recurrences in our population was similar to that reported elsewhere (17,18,39,42,48,62,74). This helps support the contention of underreporting by our population. We did not calculate SP incidence rates. We feel only a portion of SPs which actually occurred are reported in the Waiver File. This may be true for many reasons. Principle among these are: a) the symptoms were not severe enough to cause the aviator to seek medical aid, b) the aviator may have sought aid in the civilian community, c) if the aviator sought aid, the SP may not have been recognized, and d) if the SP were recognized, it may not have been reported. It seems safe to assume that the recurrence rate in the USAF aircrew population should be at least that reported by others.

The mean age of those suffering SP in our group was greater than that found in other studies (4,15,17,20,30,35,44,46,49,62,63,70,74,88,90,91,95,97,105). There may be two reasons for this. After prolonged periods of G-suit positive pressure breathing, O_2 breathing, and G stress, the lungs may become more susceptible to an SP (27,86,111). More reasonable is that the aircrew population is a skewed population as far as age is concerned. Very few individuals become aviators in their teen years or during their early 20s. This early period is usually a time for college preparation and decision planning. Those who enter the military aviation community more frequently are in their middle-to-late 20s. Those who suffered an SP before reaching this point in their lives would have been rejected from the aviation program because of the almost universal disqualifying clauses regarding a previous SP.

The study group population is taller than the general population. Those with a history of SP currently flying are younger than and an average of 1.7 in taller than our entire SP population, although population norms have been getting taller over the years. The overall height of the study population helps to confirm the general feeling that SP occurs in tall, healthy males (22,40,42,43,78,90,110) and that SP may be due to traction on the apical regions of the lungs causing formation of bullae and/or blebs with eventual SP (26,107). We do not have information on the SP patients' weights at the time of their SP experience and, consequently, cannot make accurate statements regarding the weight of individuals experiencing an SP. However, the mean weight of current flyers is 6.5 lbs less than those not currently on flying status. At the time of occurrence of an SP, an aviator would be more likely to be thinner than our data presently indicate, and tall.

Some studies report a high incidence of smokers in their SP population while others do not (14,20,25,80,112). Our data agree with the former. Smokers made up 79% of our population. The exact mechanism for this relationship is unknown unless it is related to the chronic irritative qualities of cigarette smoke along with a facilitation of emphysematous pockets. We have no information on the pack-year history of the smokers at the time of their SP. Many aircrew members reported stopping smoking after their initial SP. Of interest is the lack of correlation between the individual pack-year history and the number of SP recurrences. No correlation existed between smoking and SPs occurring in an LPC or in a high-G environment. An interesting project would be to study SPs in future populations to determine whether the incidence of SP decreases with a decrease in the number of cigarette smokers.

We found a relatively high occurrence of SP in family members. This relationship has not been previously reported, although it has been considered (70,105). Lacking other information on the involved family members, we can make no further observations. The aircrew members having family members with SP were taller than our population's mean, however.

Our population tended to seek medical attention much more quickly than its civilian counterpart (14,17,70). This action may have several explanations: a) the military aviator is conditioned to seek medical aid when he does not feel well, b) those who had symptoms were sufficiently frightened by them to seek medical attention, c) we only have information on those who sought medical attention from military physicians, not on those who sought aid from civilian physicians, d) many of those with minimal symptoms may not have sought medical attention for fear of grounding or failure to appreciate the significance of the symptoms. The individual who waited 12 h to seek medical aid after a recurrence of SP was on a camping trip in the wilderness. He could not have sought medical attention sooner. He did admit to seeking civilian medical attention and neglecting to inform his flight surgeon or the military of the SP recurrence.

Most of the symptoms elicited were similar to those previously reported (14,17,18,25,35,70,75,94,95,112,113). Our group also reported many symptoms not previously found in the literature. These "unusual" symptoms were occasionally the only symptoms experienced, e.g. sore throat. However, the SP may be incidental and unrelated to the "unusual" symptoms. One must always consider SP in any young, tall male with a positive smoking history and chest symptoms, even with no temperature or ESR elevation (70). Symptom severity is not of assistance in the diagnosis of SP for the symptoms may be of any degree. Other studies report a 10% rate of severe symptomatology with SP (14,32,70) while 28% of our group reported severe symptomatology—primarily pain and/or severe shortness of breath. The severity of our group's reported symptoms further indicates that many of those with minimal symptomatology may not have reported to military physicians. It must be remembered that this is a retrospective study and that the patients are most likely to remember the symptoms that were the most distressing to them at the time, forgetting about other symptoms.

Incapacitation is not the only danger of an in-flight SP. Just the stress of one's body malfunctioning may be the critical factor in high-performance aircraft maneuvering or in an aircraft mishap. Such added stress is especially critical in single-seat aircraft where no one can take

over for an ailing aircrewman. Even in dual-piloted aircraft, insufficient time may be available to correct a deteriorating situation during critical maneuvers.

Our data agree with the literature in that well over half of our population was either sleeping or exercising minimally at the time of the SP (16,18,25,28,39,40,56,70,75,95,105,112). The time of SP occurrence has little, if anything, to do with activity. The only detractor to this general statement is the relatively high number of SPs occurring during RDs or pressure changes. This relationship has not been previously reported (4,17,25,28,33,39,48,51,105). Although significant when considered as a percentage of all SPs experienced, the relationship is not significant when one considers the entire aircrew population. It would be difficult to devise a system to screen out RD-provocable SP individuals. We do not know whether these individuals had bullae or blebs radiologically at the time of their RD or how many RDs they had experienced before their first pneumothorax. An interesting area for investigation would be to study the RD relationship to SPs.

We found no correlation between flight experience within 24 h of an SP and its occurrence. The association of SP with flight seems to be coincidental. However, one-third of SPs did occur within 2 h of flight duty and 30% of these aviators were actually flying at the time of their SP. The danger of an incapacitating event was present in these individuals. When the proximity of an SP to a flight experience is coupled with the finding that over one-third of the aircrew members feel their SP experience could have compromised flight safety, it becomes apparent that we must try to prevent SP in flight. The large number of aircrewmen reporting that their SP could have had an adverse effect on flight safety is probably factitiously low when one considers that many individuals failed to recognize or appreciate the severity of their symptoms (Table IV). The same observations may be applied to the responses received regarding incapacitation. One quarter of those responding felt that they may have been incapacitated by their symptoms: not "impaired," but "incapacitated." This is a strong testimony by aircrew members themselves on the danger of inflight SP.

Once an individual has experienced an SP, he should be prevented from pursuing aircrew duties as long as there is a reasonable risk that he will experience another SP. The literature states that conservative therapy is neither appropriate nor adequate in the treatment of aircrew members with SP (27,62,113). Opinions regarding chemical and mechanical pleurodesis vs. parietal pleurectomy are not as well delineated (42,46,99,102). Pleurodesis is not the surgical method of choice because the recurrence rate after pleurodesis can be as high as 30% (10,17,20), no method of pleurodesis has been demonstrated as the method of choice (20,24,30,36,42,52,55,70,79,91,95,99,102,105,112,113), and pleurodesis carries high morbidity. Parietal pleurectomy has a very low recurrence rate of 0–1% (4,20,30,70,90,95) and very low morbidity and mortality (20,42,95,96). Parietal pleurectomy must be done bilaterally since there is a contralateral recurrence rate of up to 20%, and the pleurectomy must be complete (6,17,30,61,73,77,80,90,97). The requirement for a complete bilateral parietal pleurectomy is exemplified by one of our aircrew members who had a partial (apical) bilateral parietal pleurectomy. He subsequently experienced a recurrent spontaneous pneumothorax in the basal portion of one lung. The only viable alternative to complete parietal pleurectomy is to observe each aircrewman for a period of time sufficient to ensure that his risk of experiencing another SP is minimal (9 years). For all practical purposes, an aircrew member experiencing an SP must either opt for complete bilateral parietal pleurectomy or must seek a new career field. Since the incidence of SP is low (18,48,70,77,112,113), such a requirement would not present a hardship to military or civilian agencies. "Cause Undetermined" or "human error" mishaps occur frequently. We have no way of knowing how many of these mishaps have SP as a contributing factor. The U.S. military services and civilian agencies need to make changes in their current regulations regarding aircrewmen with an initial SP.

REFERENCES

1. Alder RH. A talc powder aerosol method for the prevention of recurrent spontaneous pneumothorax. Ann Thor Surg 1968; 5:474.
2. Andersen I, Nissen H. Results of silver nitrate pleurodesis in spontaneous pneumothorax. Dis Chest 1968; 54:230–3.
3. Andersen IL, Poulsen T. Surgical treatment of spontaneous pneumothorax. Acta Chir Scand 1948; 118:105.
4. Askew AR. Parietal pleurectomy for recurrent pneumothorax. Br J Surg 1976; 63:203–5.
5. Aust JB. Spontaneous pneumothorax. Post Grad Med 1961; 29:368–73.
6. Baronofsky ID, *et al*. Bilateral therapy for unilateral spontaneous pneumothorax. J Thorac Cardiovasc Surg 1957; 34:310.
   Bernard E, Meyer A. Treatment of non-tuberculous spontaneous pneumothorax. Dis Chest 1951; 19:641.
8. Bethune N. Pleural poudrage—a new technique for the deliberate production of pleural adhesions as a preliminary to lobectomy. J Thorac Surg 1935; 4:251.
9. Brock RC. Recurrent and chronic spontaneous pneumothorax. Thorax 1948; 3:88.
10. Bromley IJ. The management of spontaneous pneumothorax. Thorax 1967; 22:482.
11. Brooks JW. Open thoracotomy in the management of spontaneous pneumothorax. Ann Surg 1973; 177:298.
12. Brown TS. The chest X-ray in 55 patients with pneumothorax. Brit J Clin Prac 1977; 31:194–1.
13. Cattaneo S, Sirak H, Klassen K. Recurrent spontaneous pneumothorax in the high risk patient: management with intrapleural quinacrine. J Thorac Cardiovasc Surg 1973; 66:467–71.
14. Clark TA, *et al*. Spontaneous pneumothorax. Am J Surg 1972; 124:728–31.
15. Cohen S, Kinsman JM. Non-traumatic spontaneous pneumothorax among military personnel. N Engl J Med 1946; 235:461.
16. Cox PA, Keshishian JM. Definitive surgical treatment of spontaneous pneumothorax. Aerosp Med 1964; 35:62–5.
17. Crean IR, Rumball CA. Survey of spontaneous pneumothorax in the Royal Air Force. Thorax 1967; 22:462–5.
18. Curtis P. Spontaneous pneumothorax—a dilemma of management. J. Fam. Prac. 1978; 6:367–70.
19. Demiksian G, Lamb LF. Spontaneous pneumothorax in apparently healthy flying personnel. Ann. Int. Med. 1959; 51:39.
20. Deslauriers J, *et al*. Transaxillary pleurectomy for treatment of spontaneous pneumothorax. Ann Thor Surg 1980; 30:569–74.
21. Druepple LG, Cox WA. Simultaneous bilateral spontaneous pneumothorax. Mil. Med. 1974; 296–9.

22. Editorial. Brit. Med. J. 1958; 1:1347.
23. Ellis FH Jr., Carr DT. Problem of spontaneous pneumothorax. M. Clin. N. Am. 1954; 38:1065.
24. Fergu LS. Irvine CW, Hutchison S. Excision of bullae without pleurectomy in patients with spontaneous pneumothorax. Brit. J. Surg. 1981; 68:214–6.
25. Flux M, Dille JR. Inflight spontaneous pneumothorax: a case report. Aerosp. Med. 1969; 40:660–2.
26. Forgan P. Stature in simple pneumothorax. Thorax 1967; 22:481.
27. Fuchs HS. Idiopathic spontaneous pneumothorax and flying. Aerosp. Med. 1967; 38:1283–5.
28. Fuchs HS. Incidence of spontaneous pneumothorax in apparently healthy aircrew. Aerosp. Med. 1967; 38:1286–8.
29. Gaensler EA. Parietal pleurectomy for recurrent spontaneous pneumothorax. Surg. Gynecol. Obstet. 1956; 102:_93.
30. Gobbel WG Jr., *et al.* Spontaneous pneumothorax. J. Thorac. Cardiovasc. Surg. 1963; 40:331–45.
31. Guide for aviation medical examiners. Washington, DC: F.A.A., Oct. 1981.
32. Hansen JL. Refractory pneumothorax treated by parietal pleurolysis. Thorax 1976; 31:652–5.
33. Hayashi J. Ueber tothichen pneumothorax durch in. ..at aud emphysema. Frankfurt Ztschr. F. Path. 1915; 16:1.
34. Heath Em. Spontaneous pneumothorax in healthy young adults with particular reference to the aetiological role of aerial ascent. Am. J. Med. Sci. 1946; 211:138.
35. Herman MA. Chronic pneumothorax with recurrent acute exacerbations. Md. State Med. J. March 1976; 65–7.
36. Herman SJ, Ottecamp GC, Weisbrod GL. Pulmonary kaolin granulomas. J. Can. Ass. Radiol. 1982; 33:279–80.
37. Hickam D, Ballenger FD. The management of spontaneous pneumothorax due to emphysematous bleb. Surg. Gynec. Obstet. 1965; 120:499–502.
38. Hinshaw HC, Garland CH. Diseases of the chest. Philadelphia W. B. Saunders, 1956; 272.
39. Ho B-L. A case report of spontaneous pneumothorax during flight. Aviat. Space Environ. Med. 1973; 44:840–1.
40. Holier HV, Horwitz O. Spontaneous pneumothorax produced by ascent in airplane. J.A.M.A. 1945; 127:519.
41. Hopkirk JAC. Letter to the Editor. Aviat. Space Environ. Med. 1982; 53:183.
42. Hopkirk JAC, Pullen MJ, Fraser JR. Pleurodesis: the results of treatment for spontaneous pneumothorax in the Royal Air Force. Aviat. Space Environ. Med. 1983; 54:158–60.
43. Hyde L. Benign spontaneous pneumothorax. Ann. Intern. Med. 1962; 56:746–51.
44. Hyde L. Spontaneous pneumothorax. Dis. Chest. 1963; 34:476–80.
45. Jovnt GHC, Laird RC. Treatment of spontaneous pneumothorax with kaolin. Dis. Chest. 1958; 34:1–7.
46. Kalnins I, Torda TA, Wright JS. Bilateral simultaneous pleurodesis by median sternotomy for spontaneous pneumothorax. Ann. Thor. Surg. 1973; 15:202–6.
47. Katzwinkel J., *et al.* Intrapleural insullation of quinacrine for recurrent pneumothorax. J.A.M.A. 1973; 226:557–9.
48. Kjaergaard H. Spontaneous pneumothorax in the apparently healthy. Acta Med. Scand. Suppl. 1932; 42:1.
49. Killen DA, Gobbel WG. Spontaneous pneumothorax. London. Churchill, 1968.
50. Kleinerman J, Cowdrey CR, Stein HM. Unpublished data presented at the 1968 annual meeting, American Thoracic Society. Houston: Pediatric Herald. 1968; 9:5.
51. Kruetzer FL, Birnbaum LG, Rogers WL. Treatment of spontaneous pneumothorax by means of continuous intrapleural suction. Dis. Chest. 1952; 21:663.
52. Kurzweg FT, *et al.* Brush pleurodesis. Am. Surg. 1976; 42:581.
53. LaForest E, Henry A. Intrapleural insufflation of dicetyl phosphate to promote pleural symphysis. Dis. Chest. 1963; 43:505–8.
54. Lambert HP. Spontaneous pneumothorax and pulmonary tuberculosis. Tubercle 1956; 37:207.
55. Larnen AJ, *et al.* Intrapleural instillation of quinacrine for treatment of recurrent spontaneous pneumothorax. Ann. Thor. Surg. 1979; 28:146–50.
56. Leach JE. Pneumothorax in young adult males: descriptive statistics in 126 cases. Arch. Int. Med. 1945; 76:264.
57. Leading Article. Spontaneous pneumothorax. Br. Med. J. 1968; 1:720.
58. Leading Article. Spontaneous pneumothorax. Br. Med. J. 1975; 2:526.
59. LeFemine AA, O'Hara ET, Lynch JP. Treatment of spontaneous pneumothorax. J.A.M.A. 1956; 162:622.
60. Legrand M, Chemouille E. Spontaneous pneumothorax in women. Sem. Hop. Paris. 1976; 52:2471–6.
61. Levy IF. Spontaneous pneumothorax. Treatment based on analysis of 170 episodes on 135 patients. Dis. Chest. 1966; 49:529–37.
62. Lichter I. Long-term follow-up of planned treatment of spontaneous pneumothorax. Thorax 1974; 29:32–7.
63. Lichter I, Gwynne JF. Spontaneous pneumothorax in young subjects. A clinical and pathological study. Thorax 1971; 26:409–17.
64. Lindskog GE, Halasz A. Spontaneous pneumothorax: consideration of pathogenesis and management with a review of 72 hospitalized cases. Arch. Surg. 1957; 75:693.
65. McCormack RJM. The management of spontaneous pneumothorax. Thorax 1967; 22:482.
66. Maassen W. Spontaneous pneumothorax. Chir. Ther. Therapiewoche 1974; 24:214.
67. Manual of the medical department. U.S. Navy. 25 Nov 1980. Chap. 15–20 para. 2K. Chap 15–70 para. 2.
68. Markovits AS, Philipps RB. Lung collapse in aviation. J.A.M.A. 1957; 164:1569–71.
69. Matsumoto T, *et al.* Cyanoacrylate tissue adhesives in the treatment of recurrent spontaneous pneumothorax. Surgery 1967; 61:573–5.
70. Mattila S, and Kostiainen S. Spontaneous pneumothorax. Scand. J. Thor. Cardiovasc. Surg. 1977; 11:259–63.
71. Maxwell J. The production of pleural adhesions by kaolin injection. Thorax 1954; 9:10.
72. Medical evaluation and standards for astronaut selection. Washington, DC: NASA, Jan. 1977. 4.5.4.
73. Mercier C, *et al.* Outpatient management of intercostal tube drainage in spontaneous pneumothorax. Ann. Thor. Surg. 1976; 22:163–5.
74. Meyers JA. Simple spontaneous pneumothorax. Dis. Chest. 1954; 26:420.
75. Meyerson RM. Spontaneous pneumothorax: clinical study of 100 consecutive cases. N. Engl. J. Med. 1948; 238:461.
76. Nandi P. Recurrent spontaneous pneumothorax. Chest 1980; 77:493–5.
77. Neal JF, *et al.* Bilateral bleb excision through median sternotomy. Am. J. Surg. 1979; 138:794–7.
78. Nissen H. Pneumothorax spontaneous. Munksgaard, Copenhagen (thesis in Danish with an English summary). 1969.
79. Ofoegbu DO. Pleurodesis for spontaneous pneumothorax: experience with intrapleural olive oil in high risk patients. Am. J. Surg. 1980; 140:679–81.
80. Page A, *et al.* Spontaneous pneumothorax: outpatient management with intercostal tube drainage. Can. Med. Ass. J. 1975; 112:707–9.
81. Pecora DV. Chemical pleurodesis. Chest 1982; 82:514.
82. Penagaluru JR. Spontaneous pneumothorax. Ann. Thor. Surg. 1976; 21:85.
83. Pentti OM. Spontaneous pneumothorax. A clinical study of 166 cases. Ann. Chir. Gynaecol. [Suppl.] 1967; 160:7–61.
84. Perry KMA. On spontaneous pneumothorax. Q. J. Med. 1939; 8:1.
85. Poole GW. The management of spontaneous pneumothorax. Thorax 1967; 22:482.
86. Rahn H, Farhi LE. Gaseous environment and atelectasis. Fed. Proc. 1963; 22:1035–41.
87. Randel HW, ed. Aerospace medicine. Baltimore: Williams & Wilkins, 1971:511.
88. Reddy JP. Management of spontaneous pneumothorax. Ann. Thor. Surg. 1977; 24:93.
89. Reid JM, Stevenson JG, McEwan N. The management of spontaneous pneumothorax. Scott. Med. J. 1963; 8:171–4.
90. Ruckley CV, McCormack RJ. The management of spontaneous pneumothorax. Thorax 1966; 21:139–44.
91. Saha SP, *et al.* Management of spontaneous pneumothorax. Ann. Thor. Surg. 1975; 19:561–4.

92. Scheele J, M'uhe E, Wopfner F. Fibrin glue: a new treatment technic in persistent recurrent spontaneous pneumothorax. Chirurg. 1978; 49:236–43.
93. Schneider L, Reissman H. Idiopathic spontaneous pneumothorax: history of 100 unselected cases. Radiology 1945; 44:485.
94. Scott V, Kidera GJ. Spontaneous unilateral pneumothorax in an airline pilot: a case report. Aerospace. Med. 1973; 44 (6):667–8.
95. Singh SV. Current status of parietal pleurectomy in recurrent pneumothorax. Scand. J. Thor. Cardiovasc. Surg. 1979; 13:93–6.
96. Singh SV. The surgical treatment of spontaneous pneumothorax by parietal pleurectomy: long-term results with special reference to pulmonary function studies. Scand. J. Thor. Cardiovasc. Surg. 1982; 16:75–80.
97. Smith WG, Rothwell PPG. Treatment of spontaneous pneumothorax. Thorax 1962; 17:342–9.
98. Spengler L. Zur chirurgie des pneumothorax. Beite Klin Chir. 1906; 49:80.
99. Spontaneous pneumothorax. Brit. Med. J. 1976; 2:1407–8.
100. Standards of medical fitness (C31, AR 40-501). U.S. Army 27 May 1976 chap 2–24k.
101. Stradling P, Poole G. Conservative management of spontaneous pneumothorax. Thorax 1966; 21:145–9.
102. Thetter O. Fibrin adhesive and its application in thoracic surgery. Thor. Cardiovasc. Surg. 1981; 29:288–292.
103. U.S. Air Force AFR 160–43. 1983:para 3–19 (d), 4–19 (a), 5–19 (c) and (d).
104. Wallach HW. Intrapleural tetracycline for malignant pleural effusions. Chest 1975; 68:510–2.
105. Watt AG. Spontaneous pneumothorax: a review of 210 consecutive admissions to Royal Perth Hospital. Med. J. Aust. 1978; 1:186–8.
106. Watts RE, *et al.* Spontaneous pneumothorax: a rational approach to treatment. Med. J. Aust. 1970; 1:538–9.
107. West JB. Distribution of mechanical stress in the lung, possible factor in localization of pulmonary disease. Lancet 1971; 1:839–41.
108. Wied U, *et al.* Silver nitrate pleurodesis in spontaneous pneumothorax. Scand. J. Thor. Cardiovasc. Surg. 1981; 15:305–7.
109. Wilson KS. Spontaneous pneumothorax: a ten-year study. Mil. Med. 1970; 135:95–9.
110. Withers JN, *et al.* Spontaneous pneumothorax. Am. J. Surg. 1964; 108:772–6.
111. Wood EA, *et al.* Influence of acceleration in pulmonary physiology. Fed. Proc. 1963; 22:1024–34.
112. Zajaczkowska J, *et al.* Treatment of spontaneous pneumothorax. Bronchopneumologie. 1977; 27:438–45.
113. Zarnello JJ, and Acker JJ. Spontaneous pneumothorax in flight. Aerospace Med. 1959; 30:418–23.