흉막질환

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Resorption of Gas from the pleural space

- $Pr_{\text{pleural space (}}$normal FRC): -5cm$H_2O$ →-100cmH_2O (maximal inspiration effort)
- Gas resorption by a simple diffusion from the pleural space into the venous blood (by pressure gradient)
- Gas resorption rate

  pressure gradient of gases

  area of contact between the pleural gas and pleura

  permeability of the pleural surface

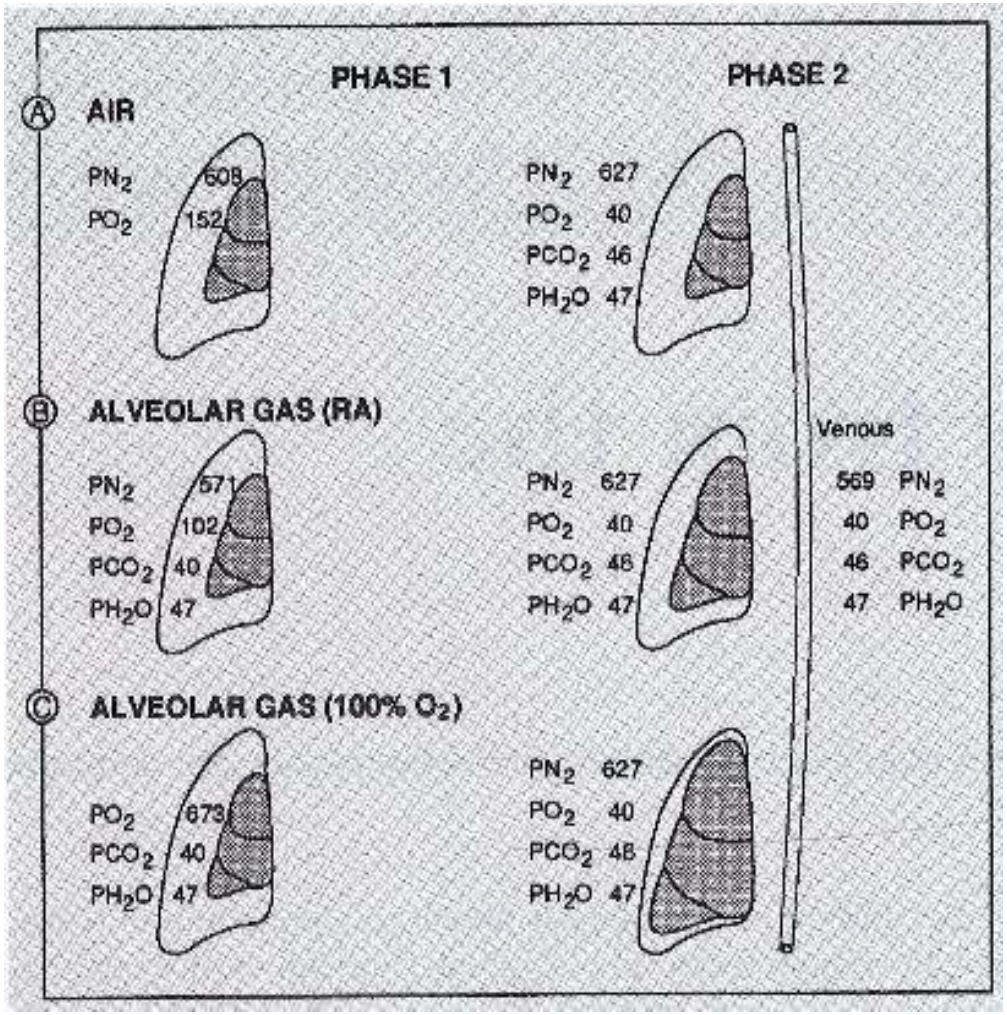
  diffusion properties of the gases

- Air in the pneumothorax: room air or alveolar air

← alveolar air(CO_2, O_2, N_2) may change depending on ventilation status or supplemental O_2

Phase of Gas resorption

- PHASE 1. Equilibration



- PHASE 2. CONSTANT RESORPTION

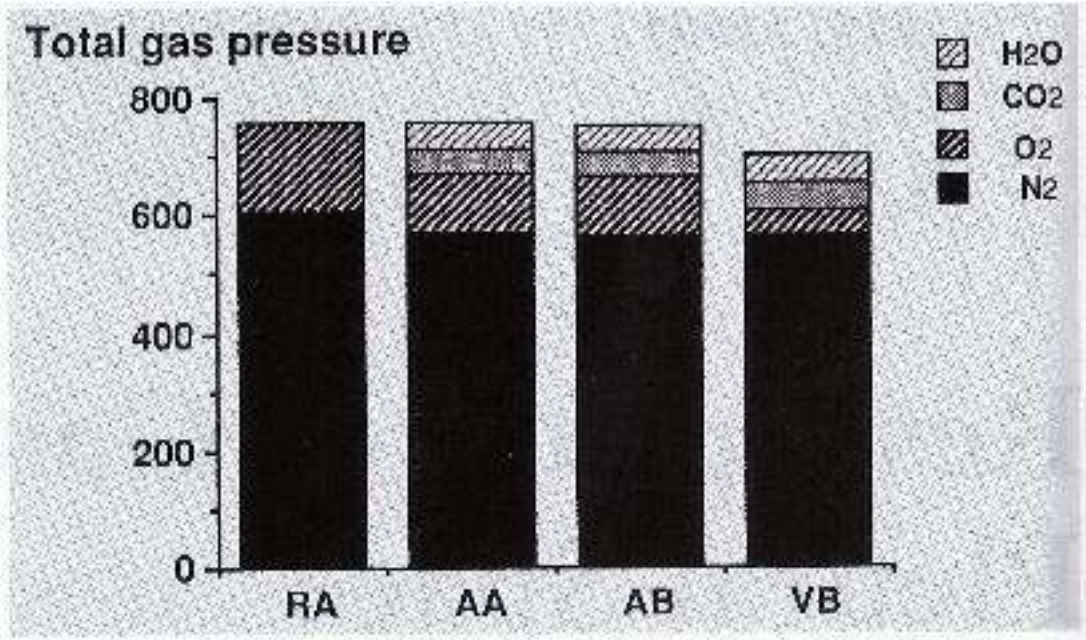


Figure 57-2. The total and partial gas pressures in room air (RA), alveolar air (AA), arterial blood (AB), and venous blood (VB). The total pressure for RA and AA is the same, whereas a small total pressure decrease occurs between AA and AB (7 mm Hg), and a further more significant decrease is seen between AB and VB (51 mm Hg). The difference between RA and VB therefore equals 58 mm Hg.

PNEUMOTHORAX

Classification of Pneumothorax
Spontaneous
Primary(PSP): No immediately apparent lung disease Subpleural bleb rupture Secondary(SSP): a complication of clinically apparent lung disease
Non-spontaneous
Traumatic Due to penetration chest trauma Due to blunt chest trauma
Iatrogenic Due to transthoracic or transbronchial lung biopsy Due to placement of central venous catheter Dut to thoracentesis or pleural biopsy Dut to barotrauma

INCIDENCE, RECURRENCE, MORTALITY

- PSP and SSP: 18-28/100,000
- PSP: thin tall male, 12-30yr
  smoking: dose-dependent(X20)
- SSP: 60-65yr
- Recurrency in PSP&SSP: 30%(16-52%)
  2^{nd} recur: up to 67%
  mostly during 6mo-2yr

- RISK FACTORS

  Pulmonary fibrosis

  Asthenic habitus

  Younger age

  Age>60

  Smoking

  Increased heegth to weight ratio

  Evidence of ELCs on chest CT

  CT ELCs on contralat lung: risk of contralat recurrence (10-15%)

Respir Med. 2007 Feb;101(2):230-6. Epub 2006 Jul 17.

Prediction of recurrent spontaneous pneumothorax: CT scan findings versus management features.

Ouanes-Besbes L, Golli M, Knani J, Dachraoui F, Nciri N, El Atrous S, Gannouni A, Abroug F.

Intensive Care Unit and Radiology Department, CHU Fattouma Bourguiba, Monastir, Tunisia.

Abstract

OBJECTIVE: To assess the association between primary spontaneous pneumothorax (PSP) recurrence and pulmonary CT scan findings, and other variables pertaining to clinical presentation and management.

METHODS: Consecutive patients hospitalized for the first episode of PSP and treated by various strategies including chest tube or pleurocatheter drainage and, in persistent pneumothorax, by chemical or surgical pleurodesis. All patients had a pulmonary CT scan examination in the week following hospital discharge in order to calculate a score combining distribution, number and size of dystrophic pulmonary abnormalities. This score as well as other pertinent clinical and therapeutic parameters were compared between patients who ultimately experienced PSP recurrence and those who did not.

RESULTS: Eighty patients (mean age: 27+/-7 yr) were admitted for PSP and had a chest drainage with either a drain or pleurocatheter. Chest drainage and hospitalization durations were 4.7+/-3.2 and 6.2+/-3.5 days, respectively. Sixteen patients required chemical pleurodesis. Dystrophic bullae were present in CT scans in 72.5% patients. After a mean follow up of 34+/-20 months, 15 out of the 80 patients (19%) had a PSP recurrence. Multivariate statistical analysis disclosed the use of pleurocatheter (OR=5; 95% CI: 1.4-20; P=0.02) and of chemical pleurodesis (OR=8; 95% CI: 1.5-47; P=0.015) as independent predictors of PSP recurrence. The severity of dystrophic lesions inferred from the dystrophic score was not statistically associated with the risk of recurrence.

CONCLUSION: Dystrophic lesions are frequently present in PSP. They are not associated with an increased risk of recurrence.

Chest. 2007 Oct;132(4):1146-50. Epub 2007 Jun 5.

Contralateral recurrence of primary spontaneous pneumothorax.

Huang TW, Lee SC, Cheng YL, Tzao C, Hsu HH, Chang H, Chen JC.

Division of Thoracic Surgery, Department of Surgery, Tri-Service General Hospital, Taipei, Taiwan, ROC.

Abstract

BACKGROUND: Primary spontaneous pneumothorax (PSP) is a common disease in young adults. With advances in its surgical treatment, ipsilateral recurrence is < 5%. However, contralateral recurrence remains a significant problem. The purpose of this retrospective study was to identify the factors associated with contralateral recurrence of PSP.

METHODS: From January 1997 to December 1999, 231 patients with PSP were reviewed and evaluated after an average of 92-months of follow-up. The clinical features and treatment of these patients were analyzed retrospectively.

RESULTS: Thirty-three of these patients had contralateral recurrence (14.3%). The average time of contralateral recurrence was 22.94 months. In the univariate analysis (after Bonferroni correction), patients with contralateral recurrence of PSP had lower a body mass index (BMI) [$p < 0.001$], and higher frequency of contralateral blebs/bullae on high-resolution CT (HRCT) of the lung ($p < 0.001$). Multiple logistic regression was performed on 128 patients with contralateral blebs/bullae on HRCT of the lung, and the results indicate that being underweight (BMI < 18.5 kg/m(2)) is an independent risk factor for contralateral recurrence (odds ratio, 5.327). All patients with contralateral recurrence of PSP received surgical treatment. Two patients had unilateral recurrences of pneumothorax during follow-up (2 of 64 video-assisted thoracoscopic surgeries, 3%).

CONCLUSIONS: Contralateral recurrence of PSP is significantly more common in patients with underweight and blebs/bullae in the contralateral lung. Single-stage bilateral surgery may be considered for these patients to circumvent the need for subsequent anesthetic and operative procedures, and additional hospitalization.

J Thorac Cardiovasc Surg. 2010 May;139(5):1241-5. doi: 10.1016/j.jtcvs.2009.07.047. Epub 2009 Sep 17.

Is prophylactic treatment of contralateral blebs in patients with primary spontaneous pneumothorax indicated?

Chou SH, Li HP, Lee JY, Chang SJ, Lee YL, Chang YT, Kao EL, Dai ZK, Huang MF.

Department of Surgery, Kaohsiung Medical University Hospital, Kaohsiung, Taiwan.

Abstract

OBJECTIVES: More than 50% of patients with primary spontaneous pneumothorax have contralateral blebs/bullae, and about a quarter will develop a contralateral pneumothorax. The purpose of this prospective study was to determine the need for elective treatment of asymptomatic contralateral blebs/bullae in patients presenting with primary spontaneous pneumothorax.

METHODS: From May 2006 through June 2008, results from 35 patients with ipsilateral primary spontaneous pneumothorax without contralateral blebs receiving unilateral video-assisted thoracic surgery, 35 patients with ipsilateral primary spontaneous pneumothorax with contralateral blebs receiving unilateral video-assisted thoracic surgery, and 16 patients with ipsilateral primary spontaneous pneumothorax receiving bilateral video-assisted thoracic surgery for positive contralateral blebs were collected. Their demographic and operating data were also recorded.

RESULTS: There was no significant difference in age, gender, smoking percentage, body mass index (kg/m(2)), blood loss, and postoperative pain among groups. There was longer operative time and length of stay in group receiving bilateral surgery. Within the follow-up period of 16.68 +/- 9.91 months (median, 17.50), no recurrence on either lung was found in the group operated on both sides, while contralateral occurrence was found in 17.14% of the group with ipsilateral primary spontaneous pneumothorax with contralateral blebs receiving unilateral video-assisted thoracic surgery within the period of 18.15 +/- 8.07 months (median, 21).

CONCLUSION: The study showed that the preemptive video-assisted thoracic surgery for the contralateral blebs/bullae effectively prevented the contralateral occurrence.

PRIMARY SPONTANEOUS PNEUMOTHORAX

Rupture of apical subpleural bleb?
Strong relationship between ELCs and PSP occurrence(CT ELCs (+) 81%)
Pneumothrax under the absence of ELCs may found: “pleural porosity’

MECHANISM OF BULLA FORMATION

- Smoking-related influx of neutrophil and macrophages→ imbalance of protease-antiprotease, oxidant-antioxidant system
- Upright human: difference in alveolar pressure between base and apex
- Ectomorphic physique: rapid increase in vertical size of thorax in adolescence affect intrathoracic pressure
- Familial patterns of inheritance

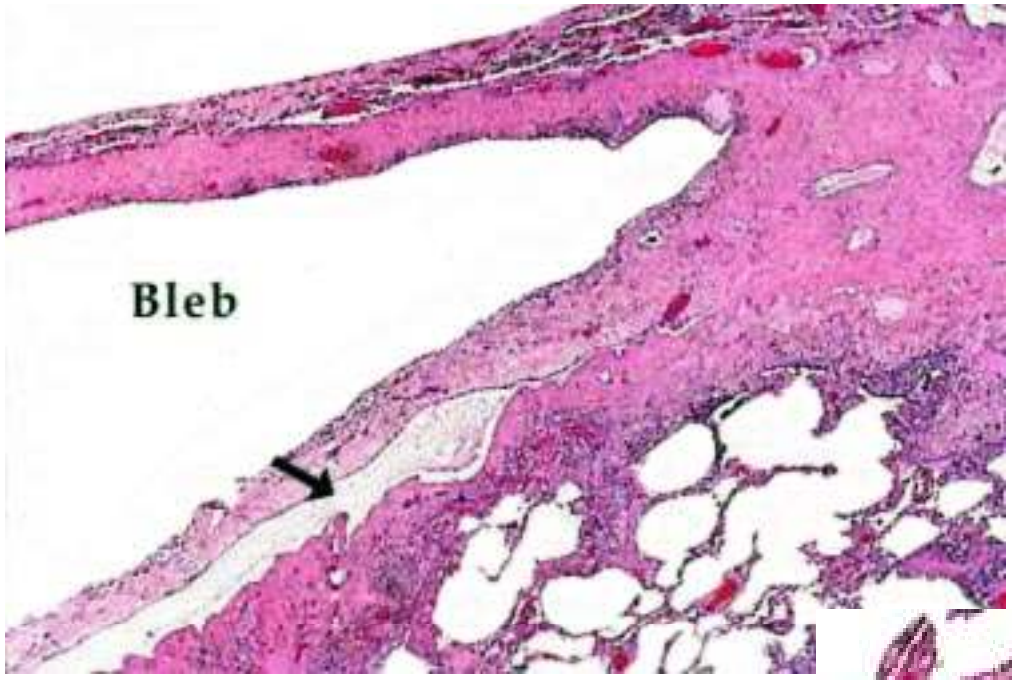
PATHOPHYSIOLOGY OF BULLAE

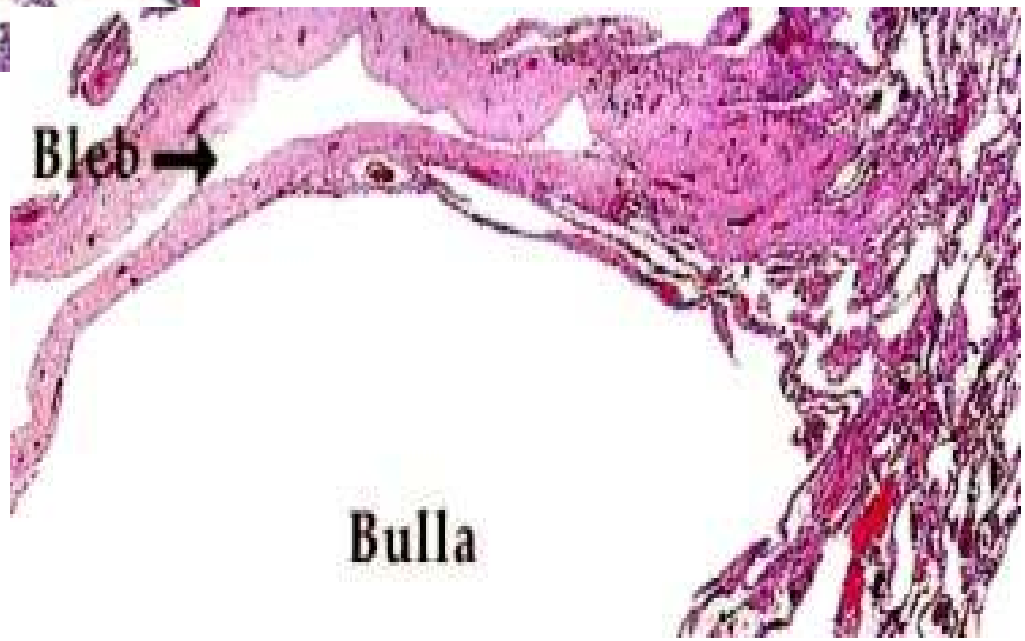
- CHECK VALVE MECHANISM
- AREA OF PARENCHYMAL WEAKNESS(Morgan)

DEFINITION

- Bleb: subpleural collection of air within layers of visceral pleura as a result of ruptured pleura. Air from ruptured alveolus dissects through the thin, fibrous layer of visceral pleura to form the bleb
- Bullae: air-filled space within the lung parenchyma as result of deterioration of alveolar tissue.. They are lined by fibrous wall and are trabeculated by remnant alveolar septa.

  bulla may developed in ephysematous lung or normal underlying lung
- Cyst: congenital/acquired, check valve obsrtrucytion of small bronchioles, inflammatory process of bronchiole


Bleb


Bleb
Bulla

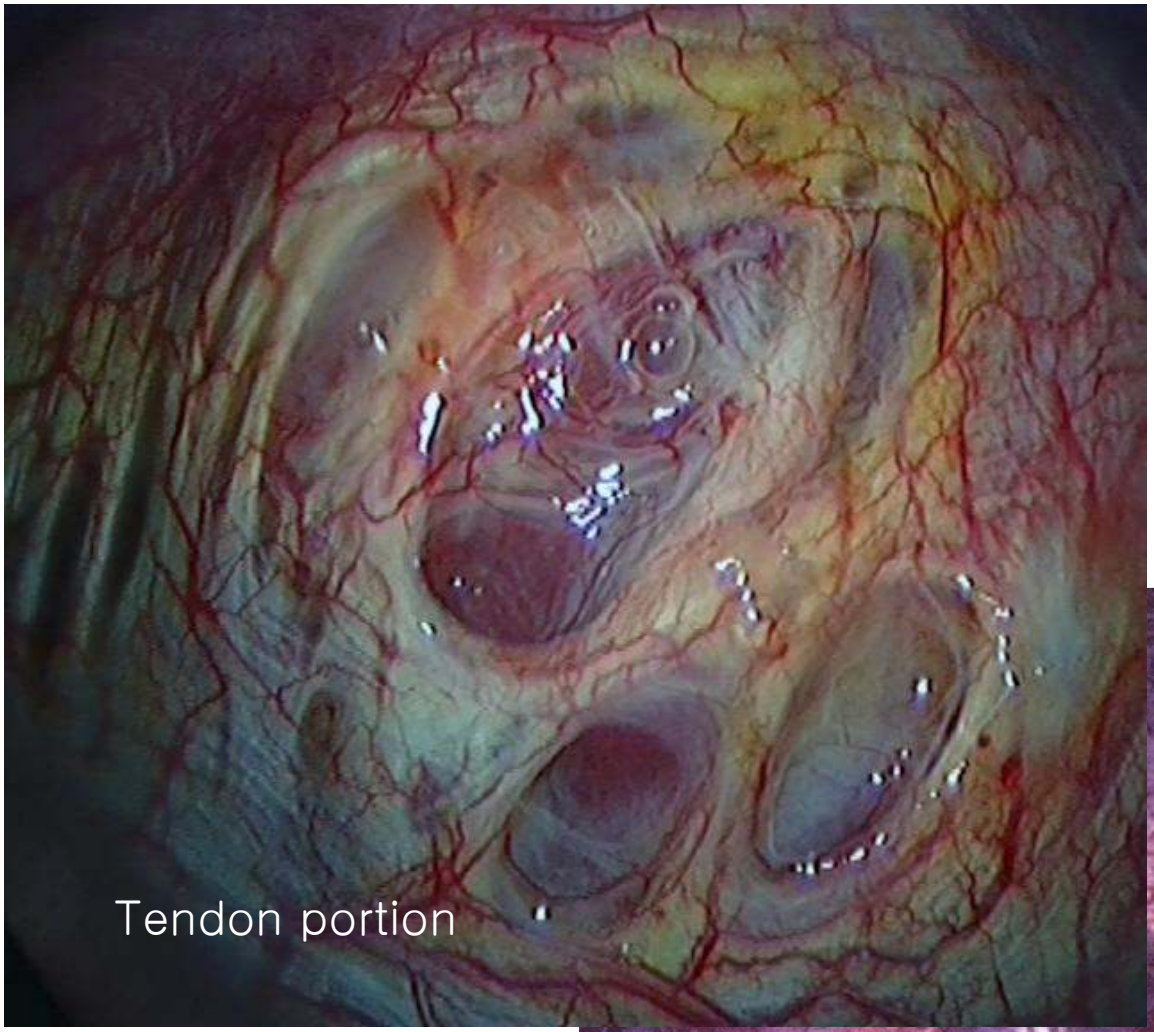
SECONDARY SPONTANEOUS PNEUMOTHORAX

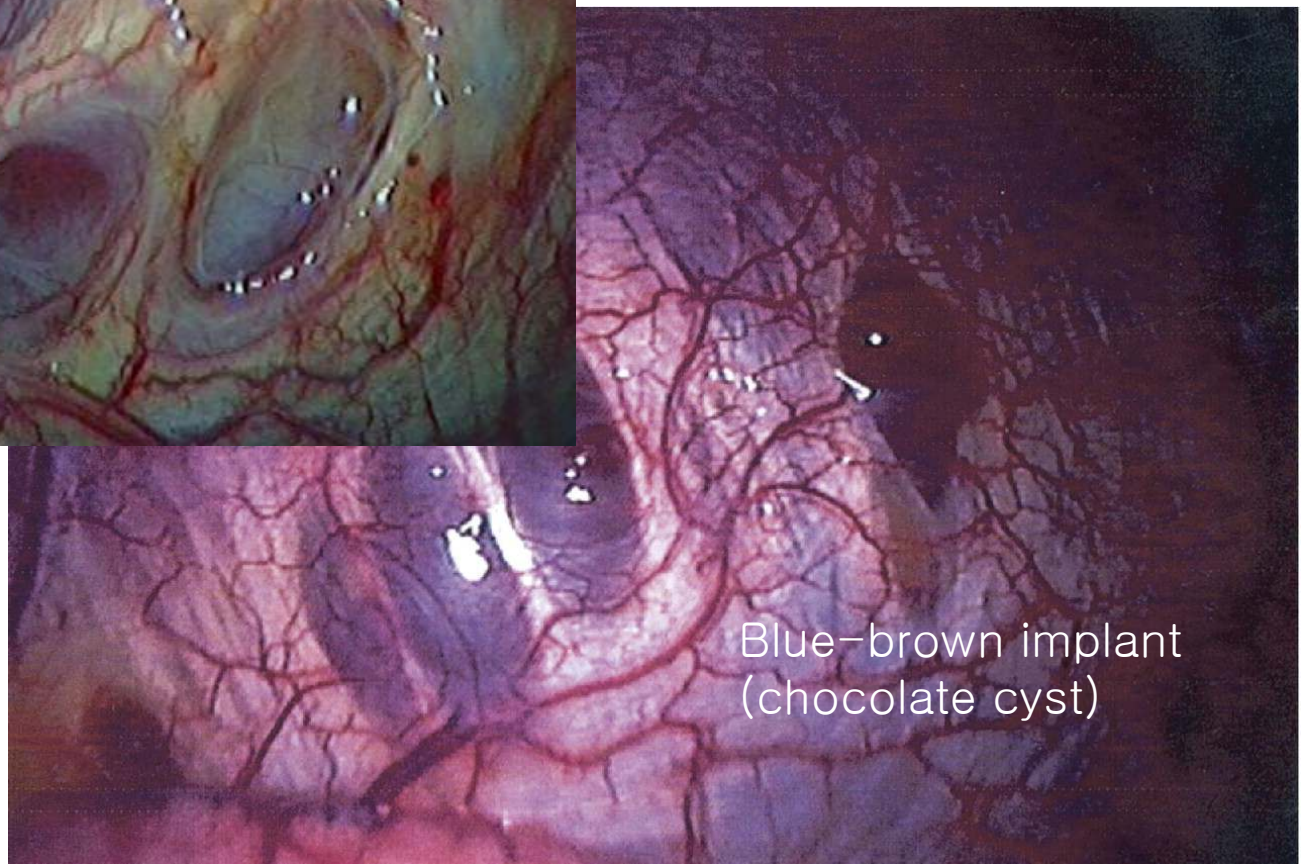
Causes of Secondary Spontaneous Pneumothorax
Airway disease
Chronic obstructive pulmonary disease Cystic fibrosis Asthma
Infectious lung disease Tuberculosis HIV and *Pneumocystis jiroveci* pneumonia Necrotizing pneumonia
Interstitial lung disease Cryptogenic fibrosing alveolitis Sarcoidosis Histiocystosis Lymphangioleiomyomatosis
Connective tissue disease(CTD) Wegener's granulomatosis Rheumatoid lung Mixed CTD
Cancer Metastatic sarcomas to the lung Mesothelioma Lung cancer
Thoracic endometriosis Catamenial pneumothorax

Osteosarcoma
Synovial sarcoma

THORACIC ENDOMETERIAL SYNDROME

- Clinical and radiologic manifestration associate with growth of endometrial glands and stroma in the lung, pleura, diaprgm, bronchial tree
- Bilateral pulmonary endometriosis/ Unilateral (Rt) pleural or diaphragmic endometriosis
- 35yr(15-54), within 72 hrs of menstration
- Catamenial pneumothorax, catamenial hemothorax, catamenial hemoptysis,


Tendon portion


Blue-brown implant
(chocolate cyst)

GOAL of THERAPY

- Suppressing the growth of endometrial implant
- Contraceptiv pills, danazol, progestational agent, Gn-RH,
- Conservative to operative
- Removal of bleb and endometrial implants
- Closure of diaphragmatic fenestration, talc pleurodesis
- Polygalactin mesh

Differences Between Primary and Secondary Pneumothorax			
		Primary	*Secondary*
Presentation	Age Chest pain Dyspnea	Usually <35 years Usual, may be severe Usually mild/moderate	Usually > 45 years Occasional Often severe
Chest radiograph	Degree of collapse Pleural reaction Other findings	Any size, often small Common, may suggest diagnosis Often mediastinal shift in complete collapse	Usually small or moderate Occasional Changes of underlying disease
Resolution on medical management	Observation alone Preferred initial intervention Persistent air leak	Often possiible, outpatient Simple aspiration or CASP Occasional, surgery indicated	Usually inappropriate, requires admission Simple aspiration or CASP
	Medical pleurodesis Surgical approach[a]	Not appropriate VATS is best option	Common, but 20% eventually resolve If high surgical risk VATS, but mini-thoracotomy may be needed

CASP, catheter aspiration of pneumothorax.
"Surgical approach includes a combination of bleb excision, apical pleurectomy, pleural abrasion, talc or doxycycline pleurodesis

IATROGENIC PNEUMOTHORAX

- Transthoracic needle aspiration(24%)
  - depth of lesion(subpleural lesion)
  - COPD
  - size(< 2cm)
  - transgression opf severalp leural planes
  - needle size, wide tranjectory angle
- subclavian vessel puncture(22%)
- Thoracentesis(22%)
- Pleural biopsy(8%)
- Mechanical ventilation(7%)

CLINICAL MANIFESTATION

- Chest pain
- Dyspnea
- SSP: limited cardiopulmonary reserve-high risk, esp in FEV1<1L, FEV1/FVC <40%
- Tension pneumothorax
- nerve stimulation

SIZE ESTIMATION OF PNEUMOTHORAX

- Plane film: underestimate
- Rhea method
- Light method
- Collin method
- ACCP
- BTS

COMPLICATION OF PNEUMOTHORAX

- PERSISTENT AIR LEAK(over 48hr)

  SSP

  Additional tube? (ACCP X)

  Recommand surgery after 4 days

  Heimich in if in high risk

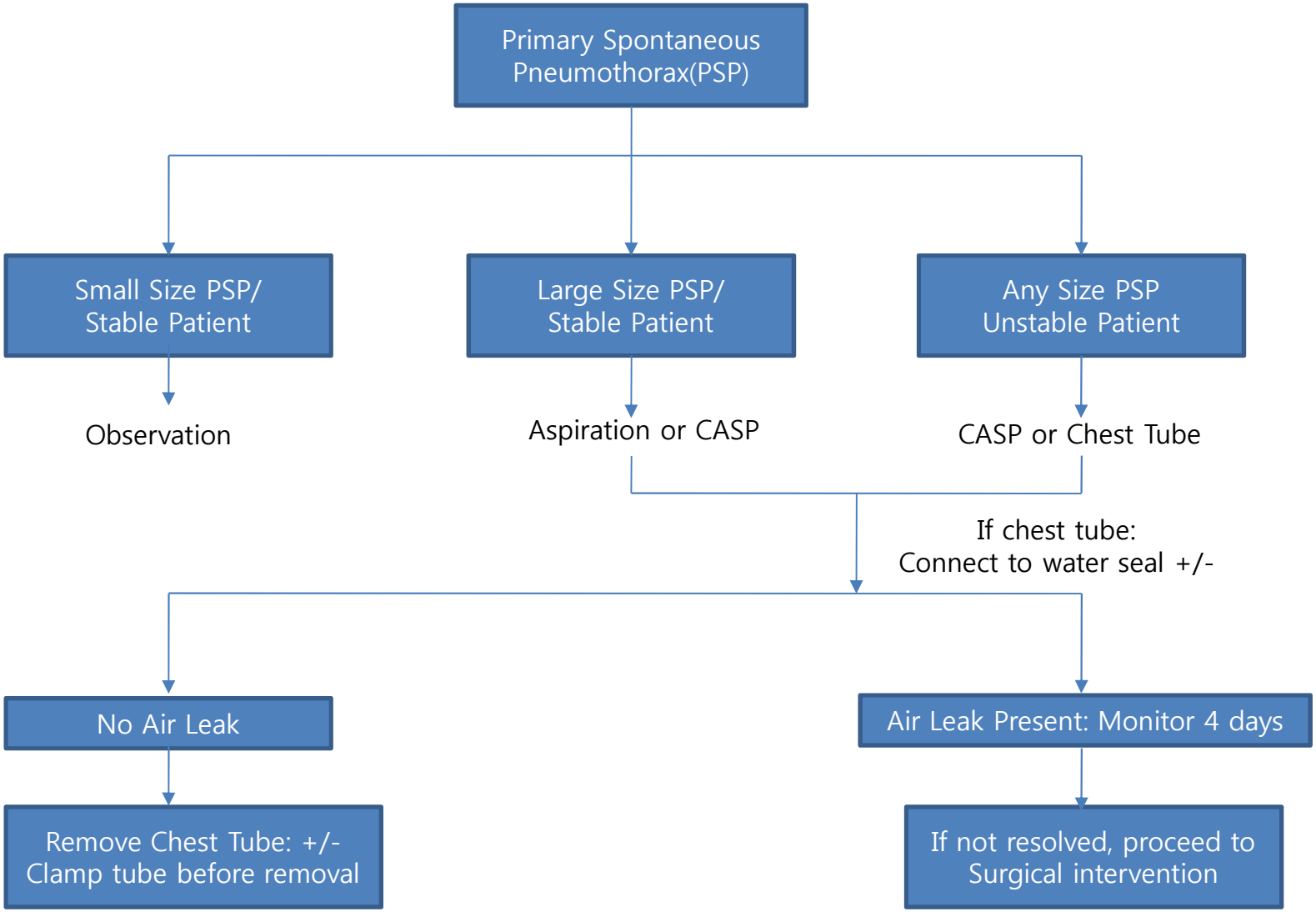
- Pneumomediastinum
- Hemothorax
- 5-10%, male predominant
- Tear of vascular adhesion or vascular bleb
- Early surgical intervention(bleeding control, evacuation, pleurodesis)

TENSION PNEUMOTHORAX

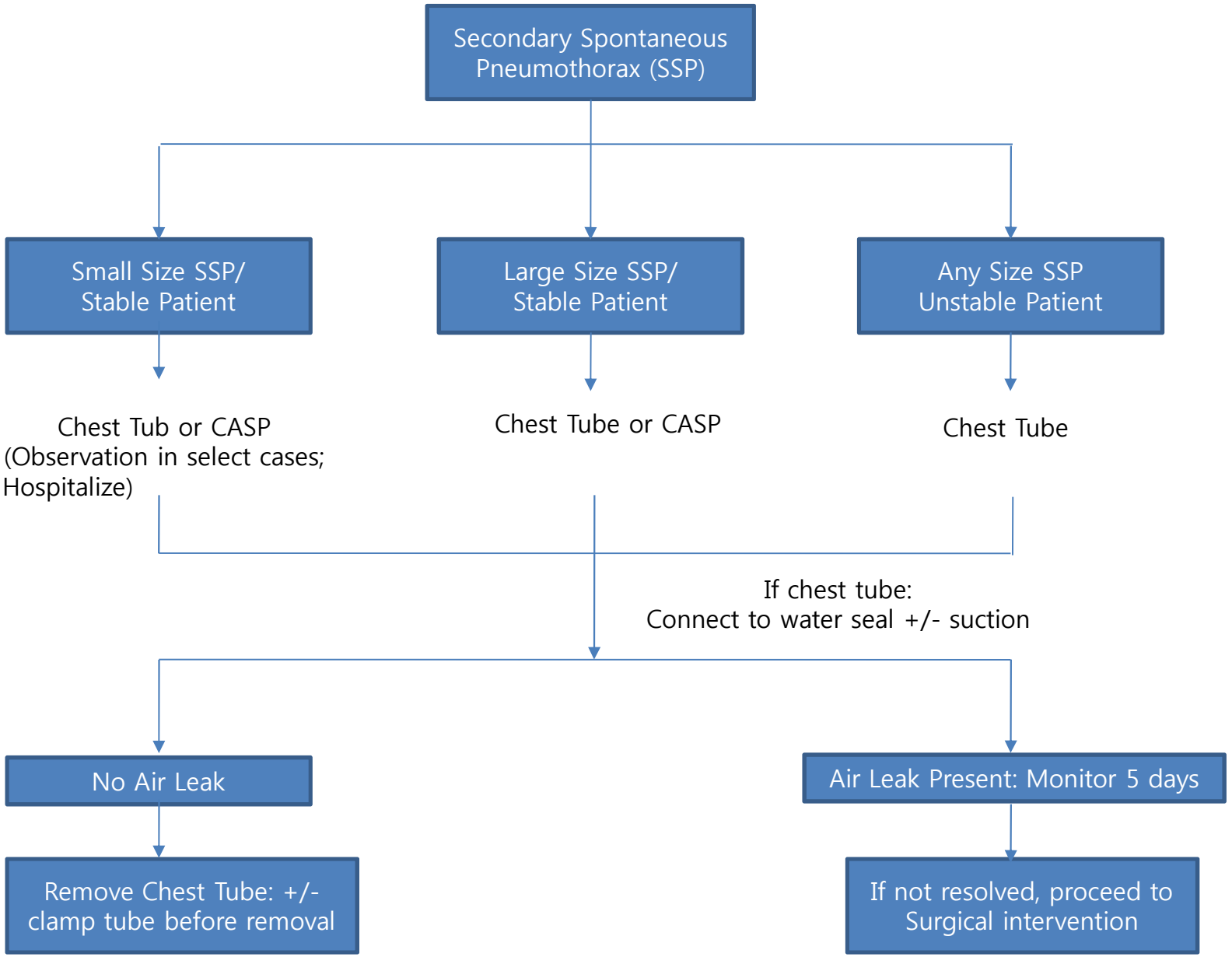
- Any pneumothorax with cardiopulmonary compromise or collapse
- Misunderstanding to mediastinal shift +diaph flattening(clinical, not radiologic)
- PSP < SSP
- ER, ICU, barotrauma
- Chest pain tachycardia, severe dyspnea, diaphoresis, hypotension, pallor
- Mediastinal shift, low CO, sympathetic

TREATMENT

- Conservative
  - Observation
  - Needle aspiration
  - Catheter drainage
  - Tube thoracostomy
- Intermediate
  - Tube with instillation of sclerosing agent
  - Mediacal thoracoscopy with talc
- Invasive
  - VATS
  - minithoracotomy



Management of first episode of primary spontaneous pneumothorax. CASP, catheter aspiration



Management of first episode of secondary spontaneous pneumothorax. CASP, catheter aspiration of pneumothorax

CHEMICAL PLEURODESIS

- Aseptic inflammation with adhesion of pleura
- Doxycyclin, talc, tetracyclin fibrin glue, silver nitrate
- Non-surgical pleurodesis can control pnx(grade A), but should be attempted only if patient unable to undergo surgery(grade B)
- NSAID should be avoided

TALC

- 5gm of talc
  by VATS spray/slurry(100c saline)
- Intravenous sedation and analgesia
- Malignant effUsion
- 91% success rate
- Fever, pneumonitis, ARDS

- DOXYCYCLINE 1000mg

  VATS/Tube
- Autologulous blood patch

  50cc, flushing with 50cc saline

VATS BLEB EXCISION AND PLEURODESIS

- One to three port
- Excision of bleb, aical pleurectomy, pleural abration, talc poudrage

Cause and Management of Recurrent Primary Spontaneous Pneumothorax After Thoracoscopic Stapler Blebectomy

Takashi Muramatsu, Mie Shimamura, Motohiko Furuichi, Tatsuhiko Nishii, Shinji Takeshita, Shinichiro Ishimoto, Hiroaki Morooka, Yoko Tanaka, Chiyoshi Yagasaki, Kazumitsu Ohmori and Motomi Shiono, Division of Respiratory Surgery, Department of Surgery, Nihon University School of Medicine, Tokyo, Japan.

BACKGROUND: As the number of patients treated by thoracoscopic stapler blebectomy increased, the postoperative recurrence rate had risen unexpectedly. We retrospectively investigated the cause and management of primary spontaneous pneumothorax recurrence after thoracoscopic stapler blebectomy.
METHODS: From March 1992 to the end of December 2006, thoracoscopic stapler blebectomy was performed in 357 patients with primary spontaneous pneumothorax at the Nihon University Itabashi Hospital. The causes and management of recurrence were investigated in 30 patients with postoperative recurrence based on items such as the resurgical observations, preoperative chest computed tomography findings, previous operative notes.
RESULTS: Among the patients with bilateral pneumothorax, young patients exhibited a higher tendency for postoperative recurrence. The most common cause was new bulla formation (28 slides, 16 of which were apparently related to the staple line and 12 of which were not related to the staple line).

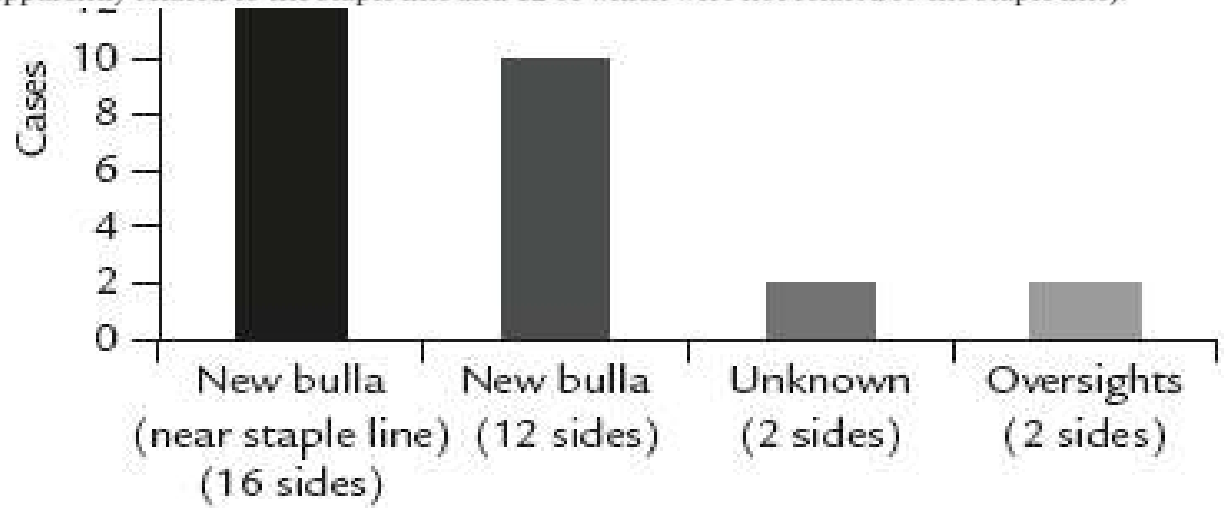


Figure 2. The causes of recurrence were investigated in 30 patients. The most common factor was new bulla formation apparently related to the staple line.

ACCEPTED INDICATION FOR OPERATIVE INTERVENTION

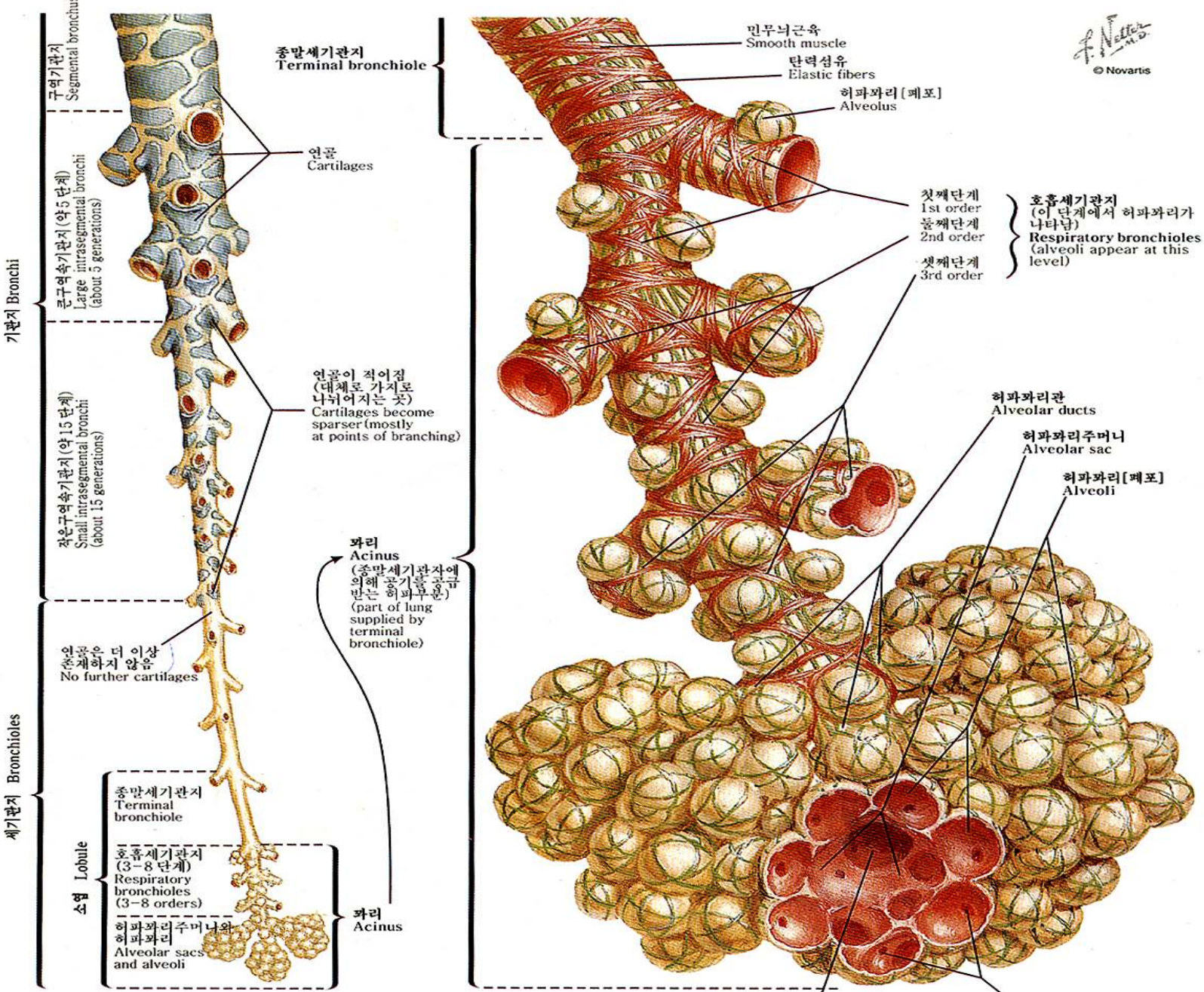
- First ipsilateral pneumothorax
- First contralateral pneumothorax
- Bilateral spontaneous pneumothorax
- Persistent air leak > 4-5 days
- Tension pneumothorax
- Spontaneous hemopneumothorax
- Contralateral pneumonectomy
- Life style and professional at risk

EMPHSEMA

- Abnormal enlargement of air space distal to terminal non-respiratory bronchiole with loss of orderly appearance of acinus
- Anatomical classification(Fitzgerald)
  - Centrilobular(proximal acinar)
  - Paraseptal(distal acinar)
  - Palobular(panainar)
- Clinical classification(Dijkman)
  - Diffuse obstructive emphysema(COPD)
  - Compensatory emphysema
  - Bullous emphysema

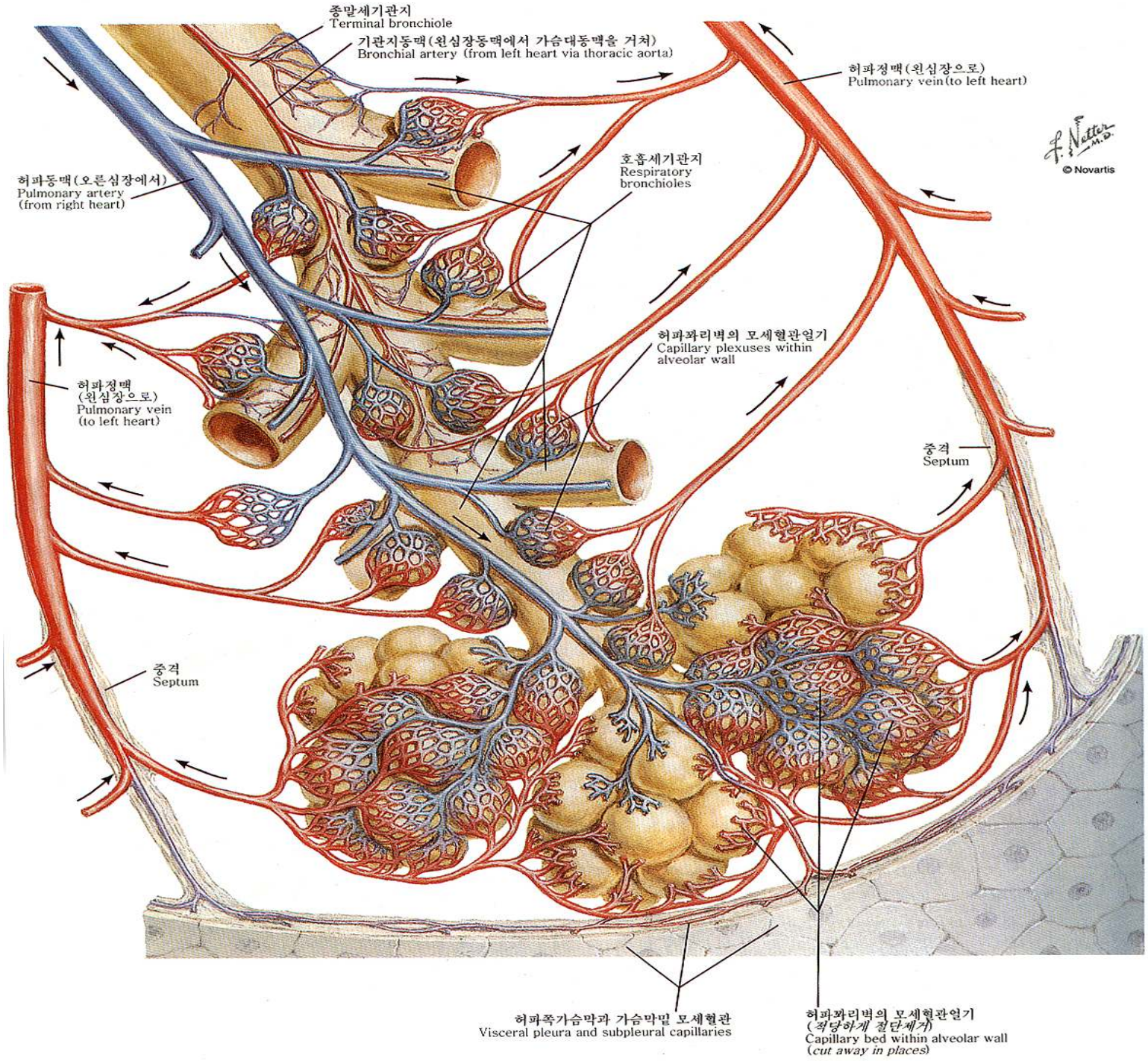
CLASSIFICATION OF BULLOUS EMPHYSEMA

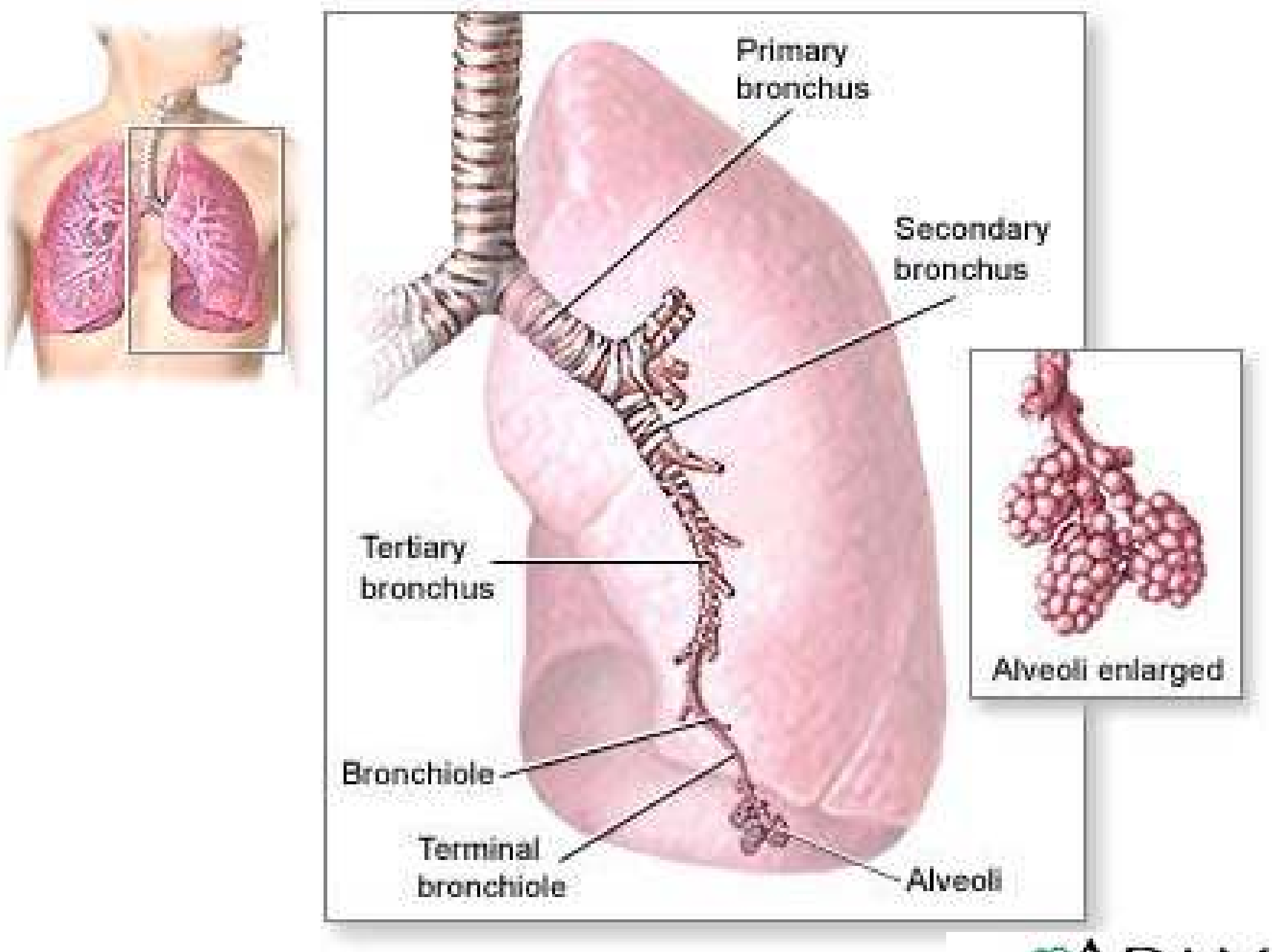
group	Bullae	Underlying lung
I	Large, single	Normal
II	Multiple	Normal
III	multiple	Diffuse emphysema
IV	multiple	Other lung disease



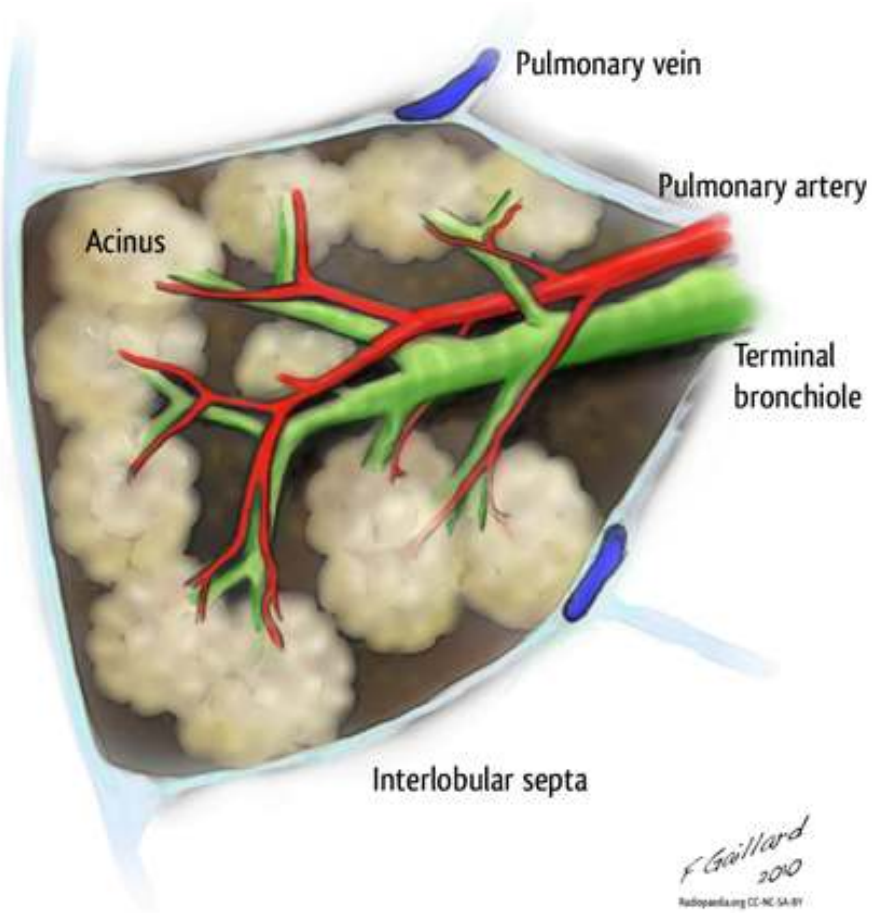
허파속공기통로의 세분류
Subdivisions of intrapulmonary airways

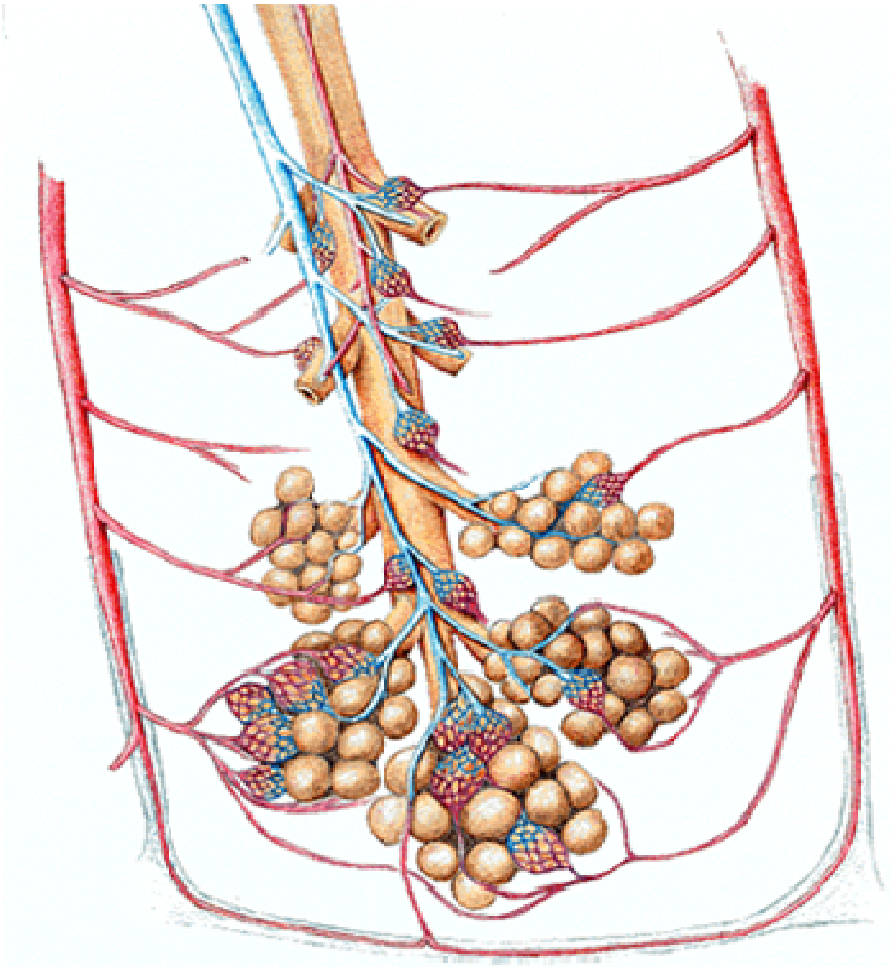
허파속 공기통로 구조
Structure of intrapulmonary airways


종말세기관지
Terminal bronchiole
기관지동맥(왼심장동맥에서 가슴대동맥을 거쳐)
Bronchial artery (from left heart via thoracic aorta)
허파정맥(왼심장으로)
Pulmonary vein(to left heart)
© Novartis
호흡세기관지
Respiratory bronchioles
허파동맥(오른심장에서)
Pulmonary artery
(from right heart)
허파꽈리벽의 모세혈관얼기
Capillary plexuses within alveolar wall
허파정맥
(왼심장으로)
Pulmonary vein
(to left heart)
중격
Septum
중격
Septum
허파쪽가슴막과 가슴막밑 모세혈관
Visceral pleura and subpleural capillaries
허파꽈리벽의 모세혈관얼기
(적당하게 절단제거)
Capillary bed within alveolar wall
(cut away in places)

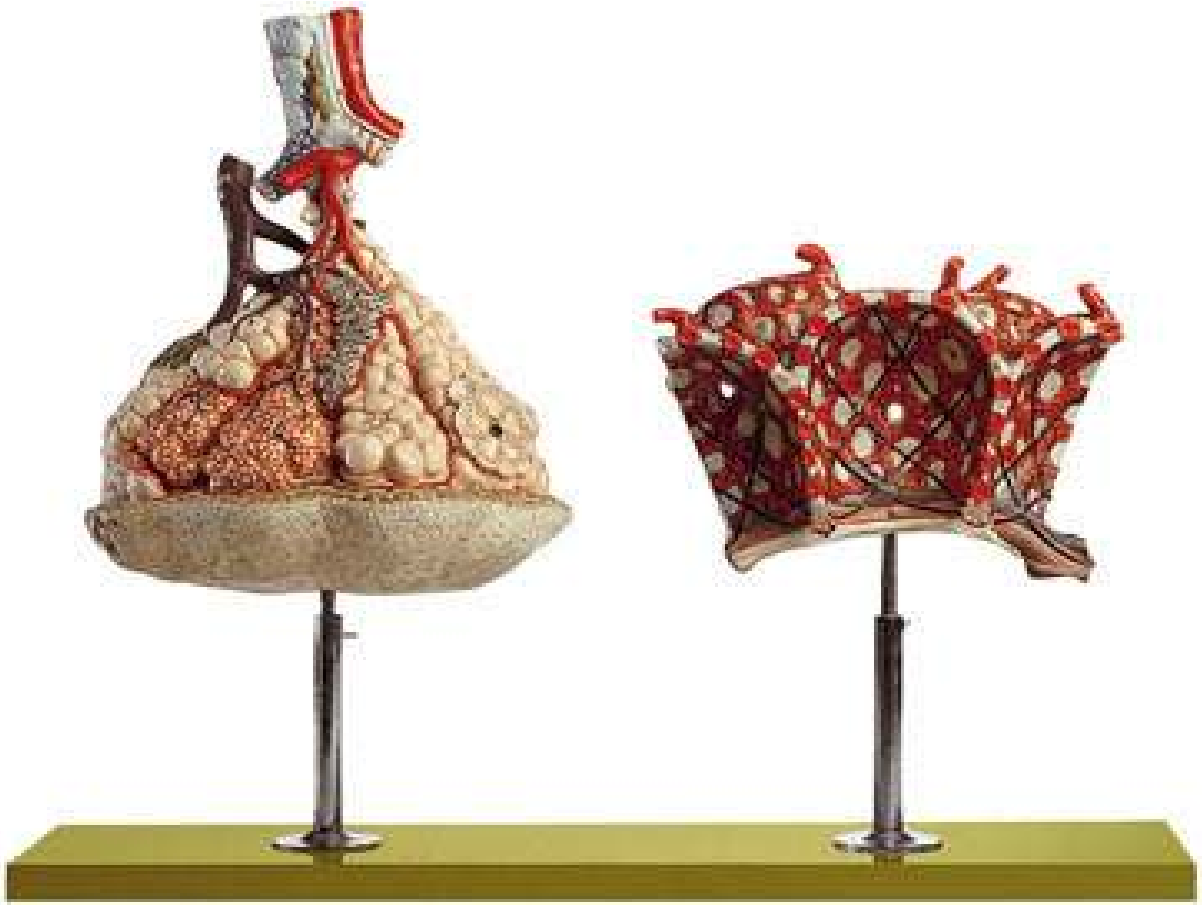

Primary bronchus
Secondary bronchus
Tertiary bronchus
Bronchiole
Terminal bronchiole
Alveoli
Alveoli enlarged
A.D.A.M.

Secondary Pulmonary Lobule

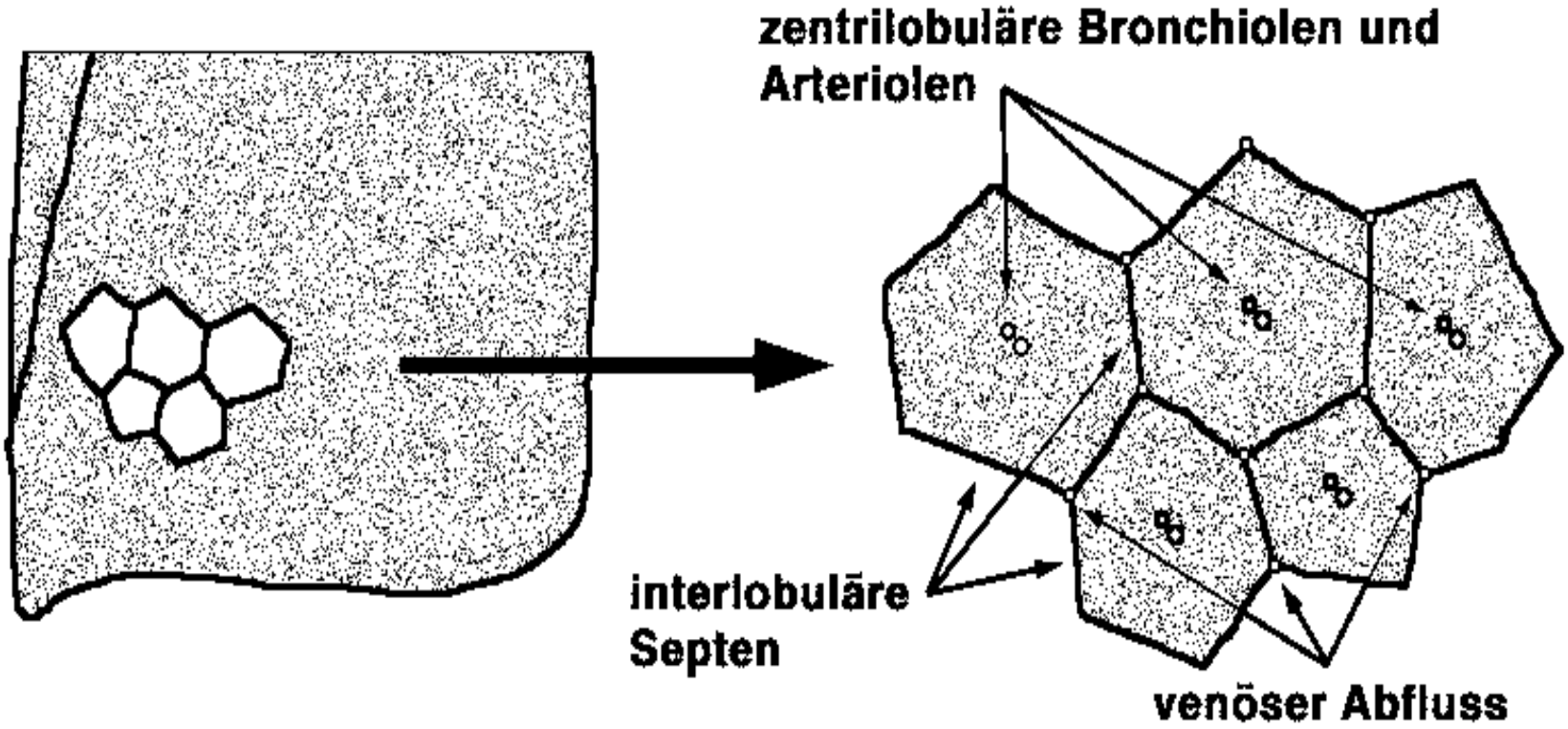




Secondary Pulmonary Lobule



Secondary Pulmonary Lobule



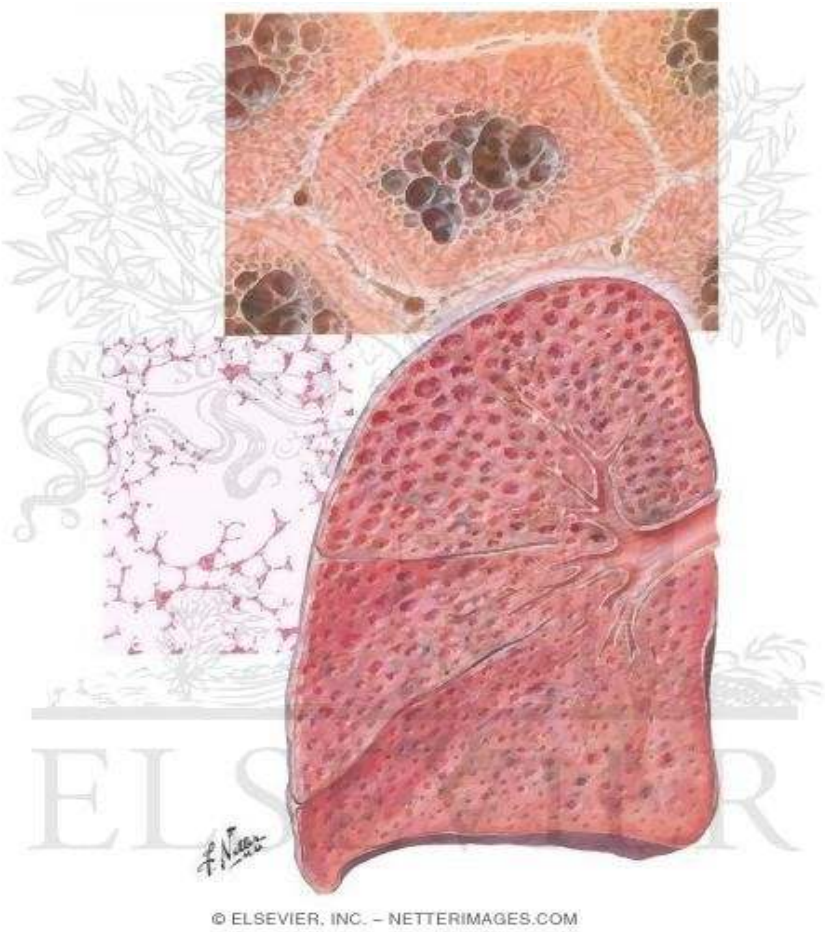
Emphysema

- Centrilobular emphysema ; M/C
  - smoking, upper lobe
- Panlobular emphysema
  - a1 antitrypsin deficiency, lower lobe
- Paraseptal emphysema
  - young adult, subpleural bleb, pneumothorax

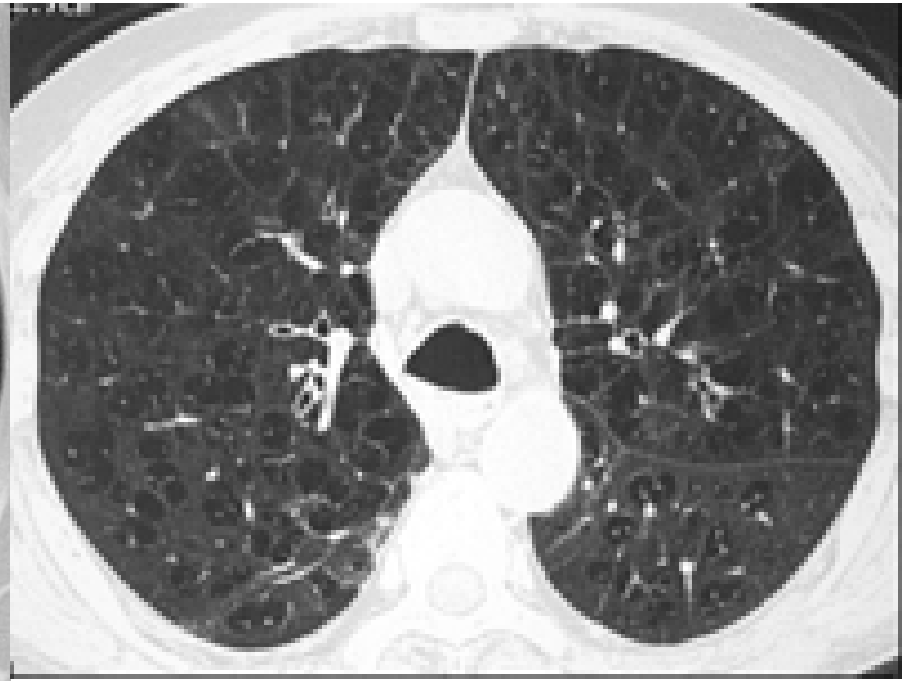
Anatomically ; **Secondary pulmonary lobule !!**

Centrilobular Emphysema

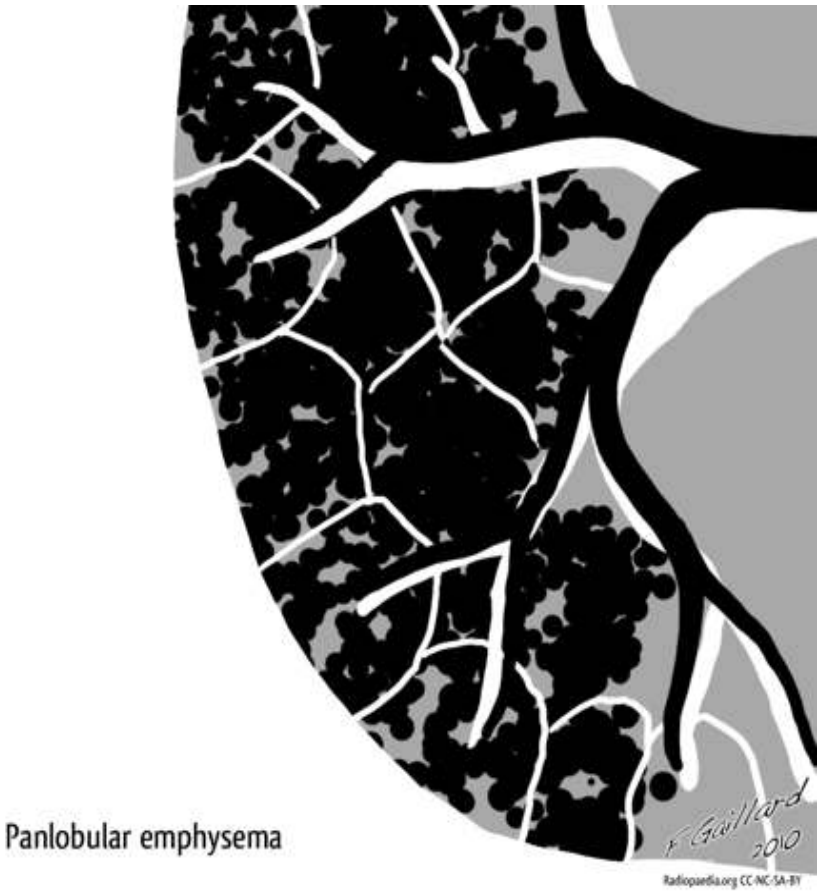
Centrilobular emphysema

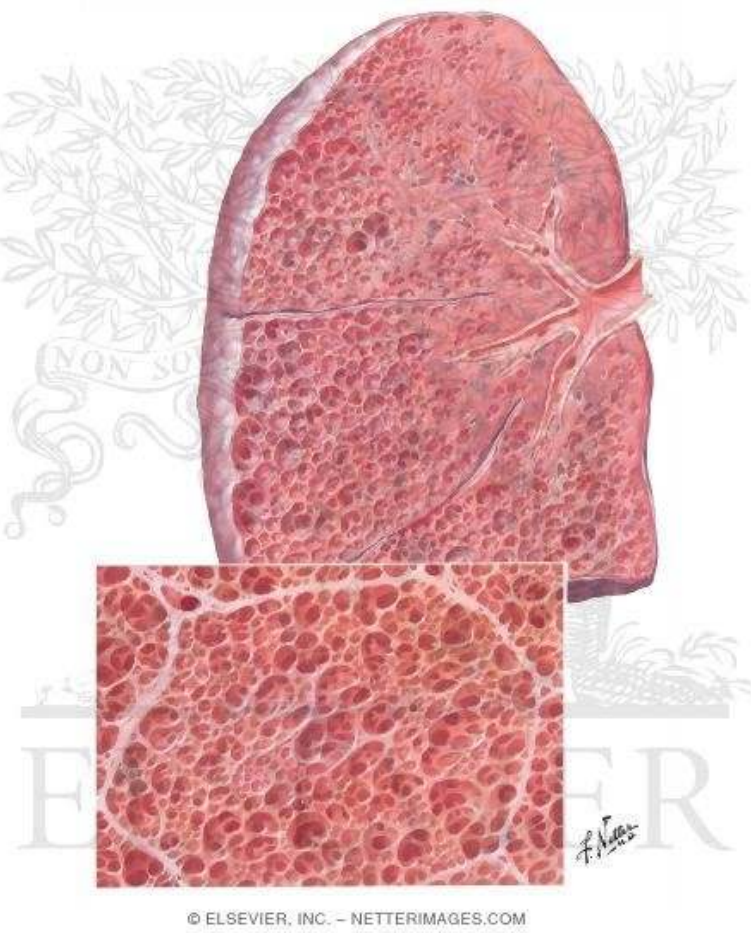


Centrilobular Emphysema

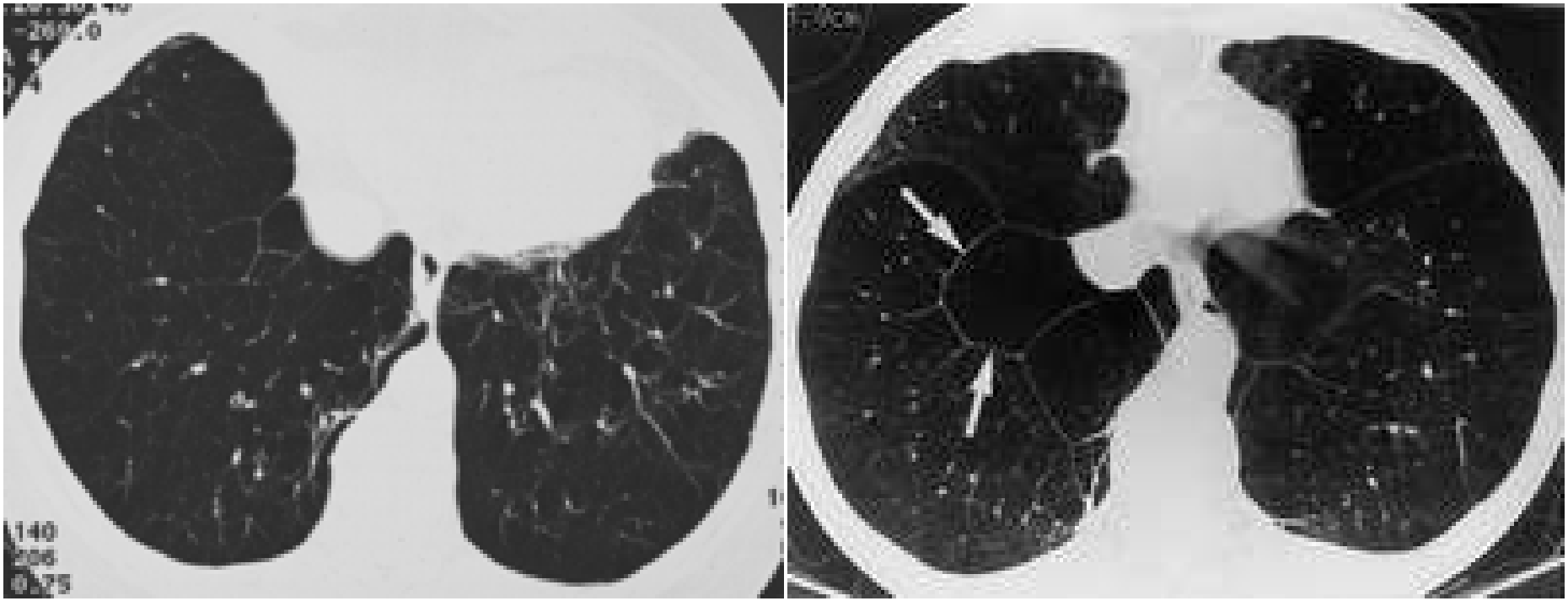


Panlobular Emphysema

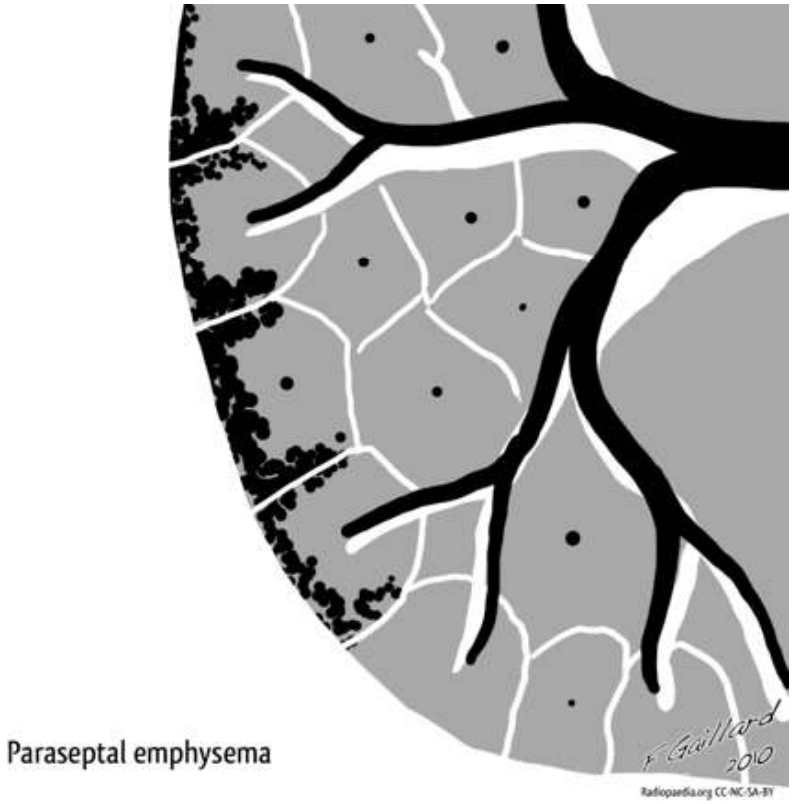


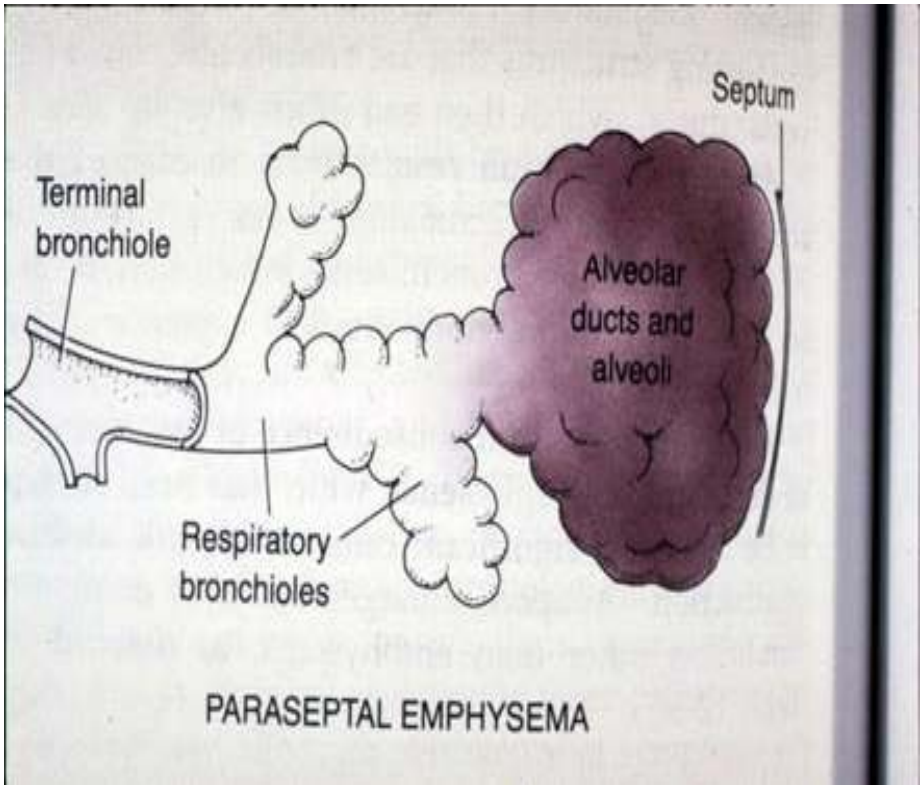


Panlobular Emphysema

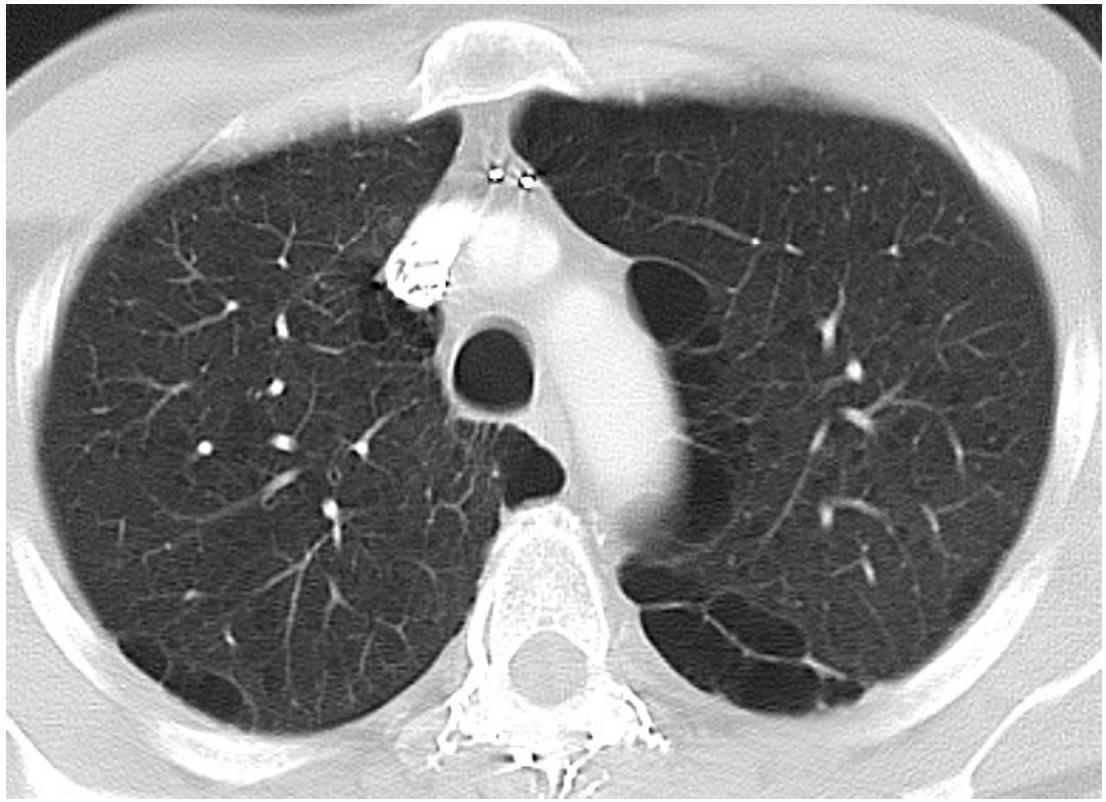


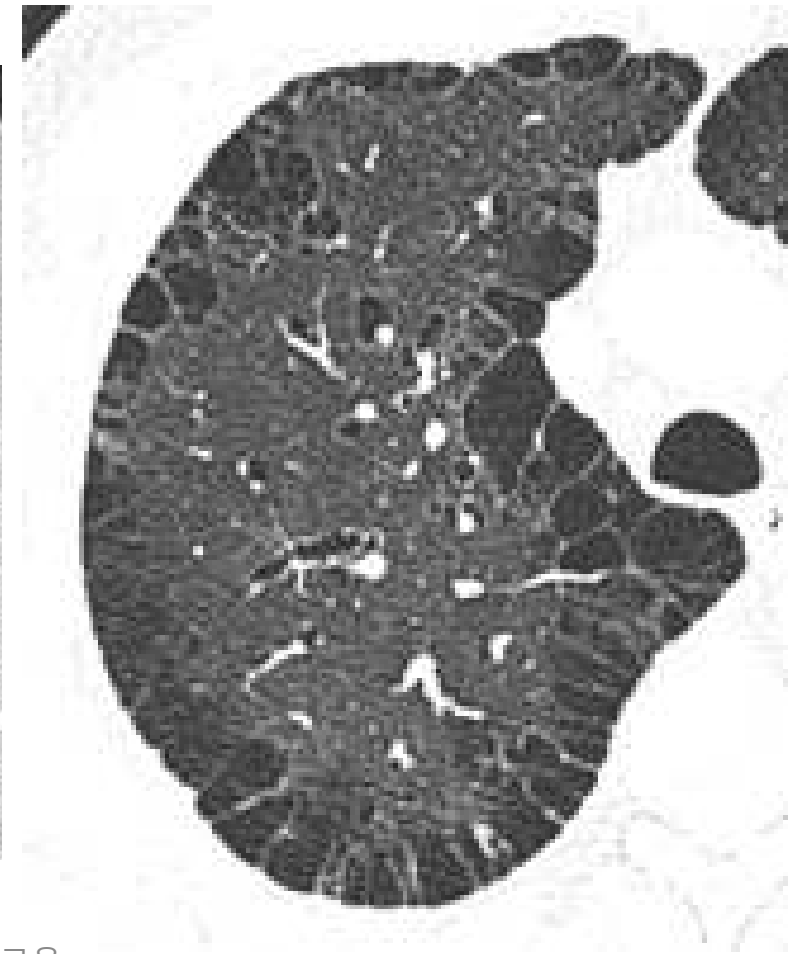
Paraseptal Emphysema



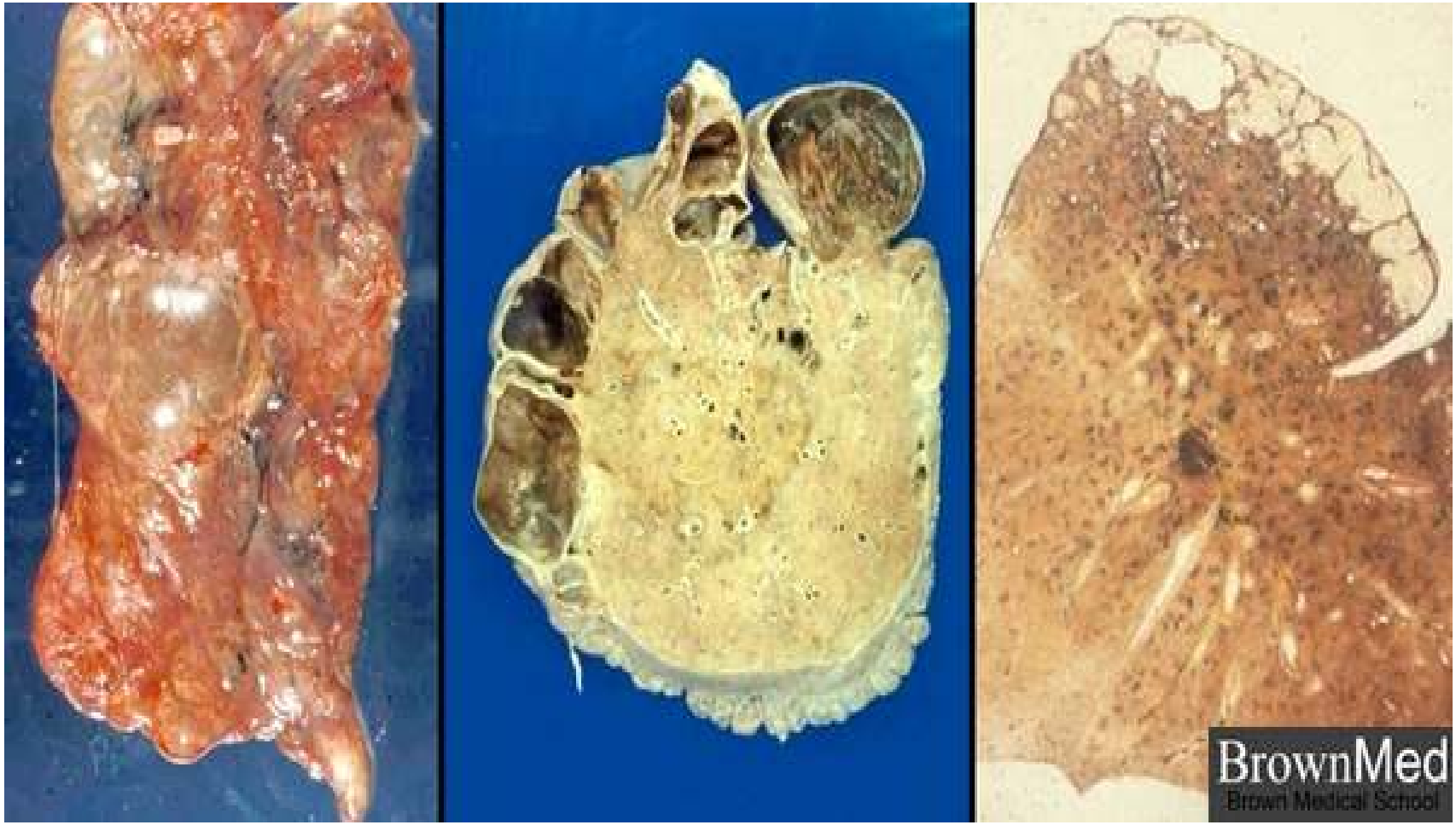


Paraseptal Emphysema





Paraseptal Emphysema



Hugh-Jones criteria for dyspnea (modified)

Grade	Definition
0	No dyspnea on exertion
I	Dyspnea on running or climbing two flights of stairs
II	Dyspnea while walking or cycling against the wind
III	Unable to walk or cycle more than 1000 m
IV	Unable to walk more than 100 m
V	Dyspnea on walking in the house, dressing, and washing

Modified Medical Research Council Dyspnea Scale

Grade	Description
0	Not troubled with breathlessness except with strenuous exercise
1	Troubled by shortness of breath when hurrying on the level or walking up a slight hill
2	Walks slower than people of the same age on the level because of breathlessness or has to stop for breath when walking at own pace on the level
3	Stops for breath after walking about 100 y after a few minutes on the level
4	Too breathless to leave the house or breathless when dressing or undressing

From Mahler DA, Wells CK. Evaluation of clinical methods for rating dyspnea. Chest 1988;93(3):

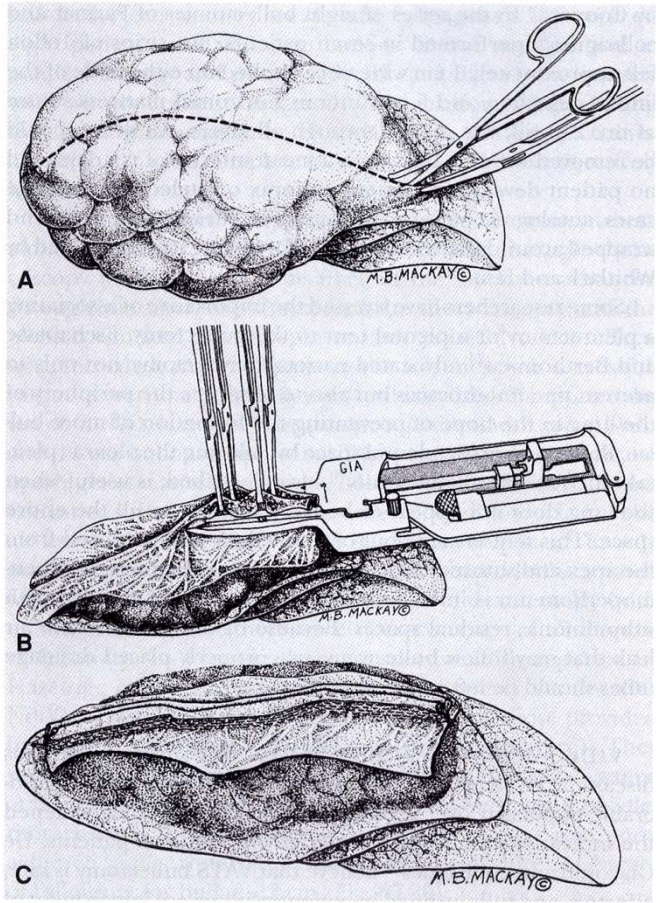
Rationale and Indications for Surgery in Patients With Complications of Their Bullae	
Indication	*Rationale for surgical approach*
Pneumothorax(first episode or recurrence)	Further reduction of function in patients already compromised Prolonged air leak High incidence of recurrences (>50%)
Infection of the bulla/ empyema Hemoptysis Chest pain	Failure to respond to medical treatment Management of significant hemoptysis Pain clearly related to air trapping during hyperventilation
Treatment of lung cancer	Documented or highly cancer suspicious lesion

Rationale and Indications for Bullectomy in Dyspneic Patients With or Without Diffuse Emphysema	
Principal indication	*Rationale*
Expansion of previously collapsed lung	Increase in vital capacity and forced expiratory volume in I second Improvement in gas exchange (higher ventilation-perfusion ratio and arterial Po_2)
Hemodynamic improvement Restoration of normal curve of diaphragm Restoration of elastic recoil and reduction in airway resistance	Increase in cardiac output; better exercise tolerance Improvement in diaphragmatic contractility and function Bullae increase the loss of elasticity in the emphysematous lung
Removal of an area of dead space ventilation	Loss of elastic recoil causes an extrinsic airway obstruction Reduction in volume of wasted ventilation Decrease in work of breathing

Selection of Patients for Surgery			
Area of inuestigation	*Technique*	*Most suitable for surgery*	*Least suitable ofr surgery*
Anatomy of bullae	Standard radiographs, CT scan	Large(more than half hemithorax) localized and unilateral bullae Enlargement over time	Multiple, small bilateral bullae No enlargement over time
Function of bullae	V/Q scans, plethysmography	Nonventilated, nonperfused bullae	Ventilated and perfused bullae
Compression index	Standard radiographs, CT scan angiography	High index(≤3/6)	Low index(<3/6)
State of compressed lung	Angiography, V/Q scan, CT scan	Good capillary filling Good washout of xenon	Poor capillary filling Retention of xenon
Severity of emphysema	CT scan, pulmonary function tests, exercise tests	Minimal or no COPD	Severe COPD Respiratory failure
Medical status	Clinical examination, EKG, echocardiography, nutritional evaluation	Young age Normal hart No comorbodities No weight loss	Older age Cor pulmonale Significant comorbidities Significant weight loss
COPD, chronic obstructive pulmonary disease; CT, computed tomography; EKG, electrocardiography;V/Q, ventilation-perfusion.			

Ground Rules for Successful Surgery

Optimal preparation before surgery
Staged operations for bilateral disease
Avoidance of air leaks
Preservation of enough lung tissue for complete reexpansion
Proper tube drainage of the pleural space
Optimal pain control
Aggressive chest physiotherapy



Operative technique.
A: Longitudinal opening of the bulla.
B: Folding of visceral pleura over the raw surface of the lung and stapling of the entire base of the cyst.
C: Completed bullectomy.
(Courtesy of Dr. J.D. Cooper)

Inclusion Criteria (Patients Must Meet All Criteria to Participate	
History and physical examination	Consistent with emphysema; BMI ≤31.1 kg/m^2 (men) or ≤32.3 kg/m^2 (women) at randomization; stable on ≤20 mg prednisone (or equivalent) daily
Radiographic	HRCT scan evidence of bilateral emphysema
Pulmonary function (pre-rehabilitation)	FEV_1 ≤45% predicted (≥15% predicted if ≥70 years); TLC ≥100% predicted; RV ≥150% predicted
Arterial blood gas (pre-rehabilitation)	P_{CO_2} ≤60 mm Hg (Denver: P_{CO_2} ≤55 mm Hg) P_{O_2} ≥45 mm Hg (Denver: P_{O_2} ≥30 mm Hg) on room air
Cardiac assessment	Approval for surgery before randomization by cardiologist if any of the following are present: unstable angina; LVEF cannot be estimated from the echocardiogram; LVEF ≤45%; dobutamine-radionuclide cardiac scan indicates coronary artery disease or ventricular dysfunction; arrhythmia (≥5 PVCs per minute; cardiac rhythm, other than sinus; PACs at rest)
Surgical assessment	Approval for surgery by pulmonary physician, thoracic surgeon, and anesthesiologist after rehabilitation and before randomization
Exercise	Post-rehabilitation 6-minute walk ≥140 meters; able to complete 3 minutes of unloaded pedaling in exercise tolerance test (before and after rehabilitation)
Consent	Signed consent forms for screening, rehabilitation, and randomization
Smoking	Plasma cotinine ≤13.7 ng/mL (or arterial carboxyhemoglobin ≤2.5% if using nicotine products); nonsmoking for 4 months before initial interview and throughout screening
Rehabiliation	Must complete pre-randomization assessments, rehabilitation program, and all post-rehabilitation and randomization assessments

BMI, body mass index; FEV_1, forced expiratory volume in 1 second; HRCT, high-resolution computed tomography; LVEF, left ventricular ejection fraction; PAC, premature atrial contraction; PVC, premature ventricular contraction; RV, residual volume; TLC, total lung capacity.
Source: From National Emphysema Treatment Trial Research Group. Rationale and designs of the National Emphysema Treatment Trial (NETT): a prospective, randomized trial of lung volume reduction surgery. *J Thorac Cardiovasc Surg* 1999;118:518. With permission.

NETT Potential Prognostic Predictors	
Age Race Gender FEV_1 % predicted RV % predicted RV/TLC DL_{CO} % predicted VC/Vco_2	$PaCO_2$ Maximum exercise capacity Perfusion ratio Homogeneity Upper-lobe predominance Hyperinflation Quality of life

VATS, video-assisted thoracic surgery;FEV_1, forced expiratory Volum in 1 second; RV, residual volume; TLC, total lung capacity; Dlco, diffusing lung capacity for carbon monoxide; NETT, National Emphysema Treatment Trial; VC, vital capacity; Vco_2, rate of elimination of carbon dioxide;$PACO_2$. Arterial partial pressure of carbon dioxide

Criteria for LVR Candidacy

	Good candidate	*Bad candidate*
History and physical	≤ 75 years Smoking cessation ≥6 months Daily prednisone ≤10 mg No significant comorbidity High motivation and compliance Good nutritional status	>75 years Evidence of reversible bronchoconstriction Recurrent infections with daily sputum Severe HTN, CHF, CAD, MI, renal disease Pulmonary HTN Cachexia or obesity (BMI >30) High-risk pleural disease (empyema, pleurodesis) Prior major thoracotomy
Imaging	Hyperinflation on chest x-ray Heterogeneous emphysema distribution Upper-lobe predominance	Increased interstitial markings Homogeneous distribution
Function and PFTs	FEV_1 ≤40% predicted TLC ≥120% predicted RV ≥150% predicted DL_{CO} ≥20% predicted 6MWT >140 m after rehab	FEV_1 ≤15% predicted DL_{CO} ≤20% predicted PaO_2 ≤55 mm Hg $PaCO_2$ ≥55 mm Hg Mean PA pressure ≥40 mm Hg

6MWT, 6-minute walk test; BMI, body mass index; CAD, coronary artery disease; CHF, congestive heart failure; DL_{CO}, diffusing lung capacity for carbon monoxide; FEV_1, forced expiratory volume in 1 second; HTN, hypertension; LVR, lung volume reduction; MI, myocardial infarction; PA, pulmonary artery; $PaCO_2$, arterial partial pressure of carbon dioxide; PaO_2, arterial partial pressure of oxygen; RV, residual volume; TLC, total lung capacity.