

PNEUMOCONIOSES

Introduction

- 1867: Zenker - pneumo = lung
conio = dust
osis = state of
- 1874: Proust - "pneumoconiosis" = "dusty lung"
- 1950: A diagnosable disease of the lungs produced by inhalation of dust (aka mineral dusts)
- 1971: Accumulation of dust in the lungs with concomitant tissue reaction to its presence
- 1973: Industrial Injuries Advisory Council (England):
pneumoconiosis is a permanent alteration of lung structure due to the inhalation of mineral dust and the tissue reactions of the lung to its presence, but should not include bronchitis and emphysema.
- 1982: WR Parkes: "pneumoconiosis" is defined as the non-neoplastic reaction of the lungs to inhaled mineral or organic dust and the resultant alteration in their structure excluding asthma, bronchitis, and emphysema.

II. Asbestos-Related Lung Diseases

A. Nature of Asbestos

1. Types: Group of fibrous silicates
 - a. Chrysotile ("serpentine") ~~~~~
 - b. Crocidolite
 - c. Amosite } amphiboles ———
 - d. Other amphiboles: anthophyllite, tremolite, actinolite

2. Indestructible
 - a. Up to 800°C
 - b. Amosite 600-900°C
 - c. Acid resistant

B. World Production and Use

a. Production (Metric Tons)

	Amosite	Crocidolite	Chrysotile
1920	200	6,100	184,000
1970	100,000	135,000	3,150,000
1983	4,157,256 (all types)		

b. Consumption (Metric Tons)

1920-1970: fourfold increase in USA

1983: 217 metric tons

C. Uses

1. Asbestos cement products - tiles, roofing, water pipes, drain pipes
2. Floor tiles (10-30% by weight)
3. Insulation and fire-proofing (shipbuilding construction)
4. Textiles
5. Paper - insulating, gaskets, wall coverings, cooking mats, stove mats, etc.
6. Friction products - brakes, clutches
7. Mining and processing

8. Other - respirator filters, cigarette filters (past), hair dryers (past)
9. Many approved uses. EPA now wants ban.

D. Populations at Risk

1. Exposures from mining to manufacture, use, removal, discarding
2. Number of workers exposed in manufacturing: 18,000
3. Construction/Renovation: 180,000 to 480,000
4. Automobile/Truck Repair: 2,000,000
5. Ship Repairs/Building: 4,000
6. Potential for current exposure: 2/3.5 million
7. Potential for past exposure: unknown

E. Clinical Conditions

1. Asbestosis

a. Definition:

Pulmonary or parenchymal fibrosis, often accompanied by thickening of visceral and parietal pleura and calcification of the parietal pleura

b. Pathology

1. macroscopic

- a. small, pale, firm and rubber in severe cases
- b. fibrotic, adherent pleura
- c. patchy (inhomogeneous) to diffuse fibrosis
- d. lower lobes predominantly affected
- e. Hilar nodes not enlarged

2. microscopic

- a. peribronchiolitis (respiratory bronchioles) - first lesions
- b. alveolitis (alveol: of respiratory bronchioles)
- c. spreads from lumen to interstitium
- d. asbestos bodies present

3. UICC/ILO Grading (paraphrased)

Grade 0: no fibrosis in bronchioles

Grade 1: fibrosis involves wall of respiratory bronchiole; no fibrosis in more distant alveoli

Grade 2: Grade 1 plus involvement of alveolar ducts or alveoli

Grade 3: fibrosis as in Grade 2, with coalescence of fibrotic alveoli

Grade 4: Grade 3 plus formation of new spaces larger than alveoli ranging up to 1 cm. "Honey combing" or bronchiolectasis. Spaces may or may not be lined by epithelium.

4. Asbestos bodies, or ferruginous bodies

- a. indicate exposure, not disease
- b. golden brown, up to 300 microns; average is 30-50 microns
- c. Asbestos fiber covered by layers of iron containing pigment
- d. dumbbell appearance
- e. Most fibers, especially chrysotile, are uncoated
- f. ratio of uncoated to coated is high: from 5:1 to 10,000:1

c. Pathogenesis

- a. Inhaled fiber may exceed 100 microns in length; 0.1-0.2 microns in diameter.
- b. first effect on respiratory bronchioles, alveoli of respiratory bronchioles
- c. Exact mechanisms of pleuropulmonary fibrosis, mesothelioma and carcinoma of lung (and other organs) are not known.
- d. Theories:
 - (1) direct physical irritation
 - (2) response to released silicic acid and metallic ions
 - (3) autoimmune reaction from antigens liberated through asbestos-macrophage interactions
 - (4) free oxygen radical generation
- e. Like silica, asbestos becomes coated with protein as it is engulfed by macrophages. It is relatively soluble compared with quartz dust, which may explain the diffuse nature of the fibrosis and relative paucity of asbestos ("ferruginous") bodies in some cases of advanced asbestiosis.

2. Hyalin Plaques

- a. bilateral, well circumscribed parietal pleura fibrosis. On CXR, may only see on one side.
- b. may calcify
- c. characteristic hyalin on pathology

3. Diffuse Visceral Pleural Thickening

- a. usually after an asbestos pleural effusion
- b. may accompany parenchymal asbestiosis
- c. costophrenic angle blunting
- d. may lead to respiratory impairment, failure

4. Pleural Effusion

- a. "benign"
- b. may occur early, i.e., 10 years since exposure
- c. serofibrinous or sometimes hemorrhagic
- d. must rule out mesothelioma, other malignancies
- e. may resorb spontaneously, and reappear on other side
- f. asbestos bodies rare in fluid

d. Clinical Presentation of Asbestosis

1. Symptoms

- a. dyspnea on exertion
- b. dyspnea greater than x-ray signs
- c. cough - common. Dry if no bronchitis.
- d. occasional pleuritic pain, chest tightness

2. Signs

- a. Bibasilar rales (50%)
- b. decreased chest expansion
- c. finger clubbing - in advanced disease
- d. pleural rub (occasional)

e. Laboratory Findings

1. Lung function tests

- a. decreased volumes (TLC, FRC, RV, FVC)
- b. Impaired gas exchange. Decreased DLCO may be earliest sign and may occur only in exercise.

- c. Can have obstructive defect (decreased flows, FEV₁)
- d. Progression: decline in volumes, DLCO; ↑(A-a)DO₂

2. Chest X-Ray

- a. fibrosis - linear; lower lobe predominance
- b. pleural plaques often present
- c. thickened visceral pleura also often present
- d. obscured heart border, diaphragm edge
- e. plaques often undetected on x-ray
- f. honeycombing may be present (later stages)

f. Diagnosis of Asbestosis

a. Clinical

- 1. history of exposure
- 2. latency (usually 15 years)
- 3. abnormal chest x-ray - linear fibrosis, plaques
- 4. restrictive pattern on PFT
- 5. impaired gas exchange
- 6. rales

* 1. and 2. essential other criteria increase likelihood with number of positives

Pathology

- 1. discussed above
- 2. even one asbestos body is significant

F. Complications/Other Diseases Associated with Exposure

1. bronchogenic carcinoma - all cell types. synergism with smoking
2. Ca of other organs - mesothelioma, GI, larynx
3. bronchitis and bronchiectasis
4. spontaneous pneumothorax - difficult re-expansion
5. Cor Pulmonale
6. TB - NO.

G. Prevention

1. substitution: most effective in this case
2. proper removal - engineering, PPE, practices
3. standard enforcement. PEL = 0.2 fiber/cc 8 hr TWA;
"action level" = 0.1 f/cc;
STEL = under litigation as of 9/89
4. smoking cessation to minimize risk of cancer and other complications

III. Talc

A. Definition

1. hydrated magnesium silicate
2. in nature, "talc" is 1-99% talc
up to 70% tremolite
(asbestine)
up to 30% quartz
3. therefore, platey and fibrous
4. New York State (NYS) talc is 70% tremolite
5. steatite - fine grained, pure
6. soapstone ore - talc substitute

B. Exposures/Uses

1. mining/milling
2. paints
3. pharmaceutical - 10-40 microns
4. electronic ceramics
5. In Rubber as lubricant. Inner tubes - parting compound
6. chewing gum
7. paper filler (esp. fibrous talc)

C. Epidemiology

1. poor information
2. NYS fibrous results in more disease than non-fibrous
3. Vermont - non fibrous

D. Pathology

1. macroscopic
 - a. fibrous adhesion of pleura
 - b. grey-white fibrosis - soft modules with poor structure or diffuse interstitial
2. microscopic
 - a. ill-defined nodules
 - b. diffuse interstitial fibrosis
 - c. foreign-body granuloma. "talc granuloma"

E. Clinical Features

1. Symptoms
 - a. occur late in process
 - b. dyspnea on exertion
 - c. cough
2. Signs
 - a. asbestosis-like
3. Chest x-ray
 - a. nodular: silicosis-like, 3-5 mm, with lobes
 - b. diffuse - (asbestosis-like) fibrosis
 - c. pleural plaques
4. Pulmonary Function Tests
 - a. nodules late - impaired gas transfer (DLCO;
↑ A-a DO₂ on exertion)
 - b. restrictive picture in fibrosis

G. Diagnosis

1. history of exposure
2. chest x-ray
3. PFT

H. Prognosis

1. NYS talc = diagnosis to death 26 years
2. slowly progressive
3. course may be fast with high exposure

I. Complications

1. ?? cancer (asbestiform)

J. Control

1. Standard
2. TLV non-fibrous 2 mg/m³ (respirable)
fibrous 2 fibers/cc greater than 5 μ

IV. Silicosis

A. Quartz

1. silicon dioxide (SiO₂) = "free silica"
2. earth's crust - silicates

B. Sources of Exposure/Uses

1. mining, quarrying, tunneling
2. stone cutting and polishing
3. abrasives and abrasive blasting
4. glass manufacture
5. fillers for paints and rubber
6. foundries

7. ceramics including refractory brick
8. boiler scaling
9. vitreous enameling

C. Populations at Risk(numbers are approximate)

- | | | |
|----|--------------------------|-------------|
| 1. | metal mining | 76,000 |
| 2. | coal mining | 80,000 |
| 3. | non-metallic minerals | 95,000 |
| 4. | stone and glass products | 507,000 |
| 5. | iron and steel foundries | 188,000 |
| 6. | non-ferrous foundries | 69,000 |
| 7. | agriculture | ? 2,000,000 |
| 8. | heavy construction | 600,000 |

D. Disease Rate Estimates

1. no reporting. no standardized diagnosis
2. NIOSH estimates 3,000-5,000/year

E. Pathology

1. macroscopic
 - a. upper lobe predominance
 - b. nodules (2-6 mm)
 - (i) intact with whirled pattern
 - (ii) cavitation (without TB) rare
 - (iii) conglomeration occurs
 - c. lymph node calcification (proportional to amt of quartz per 100 gm node)

- d. can have fibrous, adherent pleura
- 2. microscopic
 - a. quartz particles in and out of macrophages in alveolar walls, especially alveoli from respiratory bronchioles
 - b. pathogenesis (theory):
cell death → fibroblast proliferation → reticulin formation → concentric collagenous fibrosis
 - c. nodule hyalinization with cellular capsule where silica is. Hyaline has high content of carbohydrate and phospholipid (like amyloid).
- 3. miscellaneous
 - a. Amount of fibrosis is proportional to free silica content and duration of residence in lung.
 - b. Normal lungs: free silica up to 1%. In silicotic lungs, up to 20%.
 - c. Silica in lymph nodes may lead to characteristic "egg shell" calcification
 - d. Fibrosis progresses after exposure has ceased.

F. Clinical Presentation

- 1. symptoms
 - a. initially, non-productive cough. Later, sputum and infection
 - b. increasing dyspnea. Poor correlation with chest x-ray
 - c. no chest or pleuritic pain
- 2. signs
 - a. distant breath sounds
 - b. no wheezes or rales
 - c. finger clubbing uncommon
 - d. advanced cases have signs of cor pulmonale

G. Evaluation

1. chest x-ray
 - a. rounded opacities early in upper fields
 - b. increase in size and profusion of nodules over time
 - c. well-defined large opacities
 - d. egg-shell calcifications of nodes
2. lung function
 - a. no characteristic changes
 - b. reduced VC or FVC first finding - less than chest x-ray suggests. (vs. asbestosis)
 - c. reduced FEV₁/FVC and TLC later
 - d. impaired gas exchange (O₂ desaturation) with exercise and with conglomeration
 - e. resting A-a O₂ difference increases with advanced stages
3. other
 - a. biopsy - rarely necessary
- scalene node may suffice
 - b. EKG - changes seen with cor pulmonale
 - c. Rheumatoid factor and ANA (circulating autoantibodies) may be present with or without arthritis. Larger necrotic nodules, positive RF = Caplan's Syndrome.

H. Diagnosis

1. occupational history
2. chest x-ray
3. PFT

4. exclusion of other conditions: e.g., isolated conglomeration - R/O Cancer. Calcification of nodes or nodules - R/O TB, histoplasmosis.

I. Complications

1. tuberculosis - common
 - * suspect with: sudden change of chest x-ray; productive cough; weight loss; hemophysis
2. atypical mycobacteria - supplanting M. Tb in many regions of USA
3. cor pulmonale - not common. Occurs after silico-Tb and pulmonary hypertension
4. scleroderma - ? related
5. cancer - ? caused. same evidence in humans suggestive. animals - yes.
6. spontaneous pneumothorax - uncommon

J. Treatment

1. Poly-2-vinylpyridine-N-oxide (PVPNO) - prevents progression in animals. toxic and mutagenic.
2. Tetrandrine - from root of stephania tetrandrina, American plant. used in China. appears to break down collagen. decreases opacities on chest x-ray. in monkeys, decreases hyalin in nodules. does not alter function. ? change progression (unlikely). no controlled studies.
3. corticosteroids - no help. potential harm (TB)
4. active TB - 3 drugs
5. positive PPD - prophylaxis for 9-12 months
6. heart failure - diuresis

K. Prevention

1. PEL in mg/m³:

$$\text{respirable conc} = 10 + [\% \text{ resp quartz} + 2]$$

L. Acute Silicosis

1. Origins

- a. high exposures to free silica over short time
- b. free silica mostly of small particle size (1-2 microns)

2. Pathology

- a. macroscopic - widespread fibrosis
- b. microscopic - alveolar proteinosis identical to PAP. Birefringent particles can be demonstrated in areas - not diffuse fibrosis with silicotic nodules. If present, they are smaller and less organized.

3. Clinical Presentation

- a. symptoms - rapidly progressive breathlessness over a period of a few weeks, weight loss, productive cough, pleuritic chest pain
- b. signs - finger clubbing, rales

4. Evaluation

- a. PFT: restrictive pattern with marked decrease in TLC. impaired gas exchange, even at rest
- b. chest x-ray: diffuse alveolar air-space filling ("ground glass") appearance or like miliary TB (fine nodular)

5. Diagnosis

- a. same as silicosis, except:
- b. lavage and biopsy more likely and are very useful
- c. rapidly fatal - within one year

M. Other Aspects of Silicosis

1. free silica:
 - a. quartz: stable up to 867°C
 - b. tridymite: stable from 867°C to 1470°C
 - c. cristobalite: stable from 1470°C - 1723°C
(melting point 1723°C)

Fibrogenic properties of silica increase from quartz through cristobalite.

Quartz < Tridymite < Cristobalite

2. (b) and (c) are formed in:
refractory bricks
other highly silicious ceramics
foundry sands
straight and flux-calcined diatomite
3. Silicates = SiO_2 combined with various cations
 - a. "silicatosis" of silicate pneumoconiosis - similar to silicosis in many respects
 - b. compounds: diatomaceous earth
kaolin clay (China clay)

V. Coal/Carbonaceous Dust

A. Terminology

1. coal worker's pneumoconiosis ("CWP") - 1942
2. "anthracosilicosis" - disease as a result of exposure to both anthracite and silica (carbon and silica)
3. "black lung" - administrative term. includes any of the pulmonary conditions present in a miner's chest
4. CWP terminology
 - a. simple CWP - discreet macules or nodules < 5 mm
 - b. complicated or infective pneumoconiosis = disease considered to be due to TB complicating CWP

- c. progressive massive fibrosis ("PMF") = large confluent masses of dust and collagen fibrosis

B. Sources of Exposure

1. coal mining - face workers
 - a. surface work - low dust
 - b. trimming - high dust
2. graphite = crystalline carbon and impurities (3-5% quartz)
 - a. refractory ceramics and crucibles - heat resistant
 - b. foundry facings - heat resistant
 - c. steel and cast iron for hardness
 - d. pencils, lubricants, electrodes
3. lamp black = smoke of hydrocarbon flame - amorphous carbon
4. carbon black = flames of natural gas or petroleum distillation. crystalline carbon. used as filler and color in rubber, plastics, records, printing inks, electrodes, decoloring agents

C. Epidemiologic Highlights

1. prevalence of radiologic abnormalities
 - a. simple vs. complicated cases:

complicated more common in Eastern Pennsylvania;
rare in Colorado
 - b. rank related? $\uparrow C$ $\downarrow Q$
2. Progression relates to profusion at first visit and presence of circulatory autoantibodies (e.g., RF).
3. Simple does not carry increased mortality and pulmonary function usually normal.

D. Pathology

1. Simple Pneumoconiosis

- a. macroscopic - dust macules interspersed with unpigmented upper lobe indurated nodules. 2-5 mm, and softer than silica
 - b. microscopic - dust in and out of macrophages near respiratory bronchioles. some reticulin. nodules - random collagen (reticulin collagen greater than silicosis). centrilobular emphysema with dust - ? chemical significance in this setting
2. Progressive Massive Fibrosis (PMF)
- a. macroscopic - variable shape and does not respect architecture of the lung (upper lungs). hard, rubbery, black surface. coalescence greater than 3 cm is definition. cavitation - melanoptysis
 - b. microscopic - same as simple CWP nodules. vessels obliterated. arterial obstruction may cause necrosis
3. Rheumatoid Coal Pneumoconiosis ("Caplan's Syndrome")
- a. generally, but not exclusively, accompanied by R.A.
 - b. In one study, the prevalence of circulating RF was no different than the general population.
 - c. pathology
 - (i) macroscopic: 3-20 cm - more random distribution than above. still tends to upper cut surface. alternates black and grey-white to yellow bands (dust and necrotic collagen). can cavitate (necrotic) or calcify. coal dust macules or nodules uncommon
 - (ii) microscopic: centers necrotic, then macrophages and fibroblasts; then collagen and plasma cells. striking endarteritis at periphery with plasma cells. no TB.
4. Diffuse Interstitial Fibrosis
- a. associated with heavy dust pigmentation

E. Clinical Presentation

1. Symptoms
 - a. none specific up through category A except probably chronic bronchitis
 - b. PMF - cough, sputum
 - c. rheumatoids may have hemoptysis (AFB negative)
 - d. DOE
2. Signs - more reflective of bronchitis or emphysema

F. Evaluation

1. Lung Function
 - a. miners have (slightly) lower FEV₁ and FVC than non-miners
 - b. simple CWP can have reduced DLCO and (A-a) DO₂
 - c. PMF - results variable, but can see ↓TLC, ↓VC, ↑RV, ↓DLCO and ↑(A-a) DO₂
 - d. rheumatoid nodule(s) - little abnormality
 - e. some physicians say ventilatory capacity is the best guide to disability
2. X-Ray
 - a. q > r > p on ILO scheme
 - b. profusion grades 1-3 associated with increased retained dust. Grade 3 spreads to whole lung.
 - c. large opacities form
 - d. rheumatoid nodule: 3-30 cm, irregular, calcified
 - e. RF is positive in Caplan's.
 - f. Cavitation requires search for TB.

G. Diagnosis

1. occupational history
2. chest x-ray
3. differentiated Dx:
 - a. TB
 - b. cancer
 - c. granulomatous lung disease
4. disability
 - a. controversial
 - b. Black Lung Law - legal norms discriminate against group
 - c. "CWP" vs. "CWD"
 - d. proof of exposure for 15 years
 - e. MD's "evaluation"
 - f. specific pulmonary function tests

H. Complications

1. TB
2. chronic bronchitis
3. cor pulmonale

I. Prognosis

1. variable

J. Treatment - none

K. Prevention

1. dust control
2. 2 mg/m³ of resp dust if Si O₂ < 5%

3. if Si O₂ > 5% - silica standard

VI. Fibrous Glass

A. Nature and Origin

1. thin streams of molten glass to steam
2. spinning off a centrifuge (à la cotton-candy)
3. add resin for insulation or bonding

B. Exposure

1. great variety depending on process
2. small % respirable
3. "VFF" - very fine fibers made since 1969
4. primarily insulators. also production and manufacture of products

C. Uses

1. insulation - pipe, rolls
2. textiles (draperies)
3. cords
4. reinforcement - cars, boats
5. refractory material

D. Disease

1. Clinical

- a. upper respiratory tract irritation - severe
- b. skin - irritant contact dermatitis
- c. lower respiratory tract = VFF
- d. animal studies - VFF carcinogenic - similar to asbestos

2. Pathology

- a. minimal tissue reaction for large fibers
- b. VFF - ? alveolitis/fibrosis

3. Epidemiology

- a. x-ray negative for coarse fibers
- b. one study of VFF showed 2-3% linear opacities
- c. mortality - equivocal. no follow-up yet done of VFF

VII. Inert Dusts

A. chest x-ray changes with little or no change in lung function:
high radiodensity

- 1. iron (siderosis)
- 2. barium
- 3. antimony
- 4. zirconium
- 5. chromite

B. low radiodensity - minimal chest x-ray changes and no lung function
change

- 1. limestone
- 2. cement (non-silica containing)
- 3. gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)
- 4. silicon carbide