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Occupational and Environmental Medicine

Coal mine dust lung disease

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Overview

Spectrum of lung diseases

Coal mine dust and the mining environment

Surveillance and evaluation

- Symptom assessment
- Chest radiology – ILO system
- Spirometry

Management

Resources

Spectrum of Coal Mine Dust Lung Disease (CMDLD)

Coal worker's pneumoconiosis (CWP)
- Classic CWP: simple and complicated CWP (progressive massive fibrosis- PMF)
- Rapidly progressive pneumoconiosis
- Mixed-dust pneumoconiosis

COPD and obstructive lung diseases caused by coal mine dust
- Chronic bronchitis (clinical diagnosis)
- Emphysema

Dust-related diffuse fibrosis

Other manifestations
- Silicoproteinosis
- Lung cancer
- Rheumatoid CWP - Caplan's syndrome

Mine environment

Coal seams greater than 60 m underground generally mined by underground methods.

Longwall mining entails the use of a machine to cut across a wide coal face while a hydraulic support system supports the roof in the immediate vicinity

Coal mining entails a large range of duties and varied jobs

Enclosed space results in potentially high-respirable dust concentrations

Dust generated during act of cutting, drilling and disturbance of settled coal mine dust by vehicles and conveyor belts.

Highest dust levels at the coal face

Roof bolting associated with higher risk of silica exposure

Respiratory hazards

Coal mine dust (CMD) is a complex mixture containing:

- Coal
- Silica
- Silicates such as mica and kaolin
- Metals such as cadmium and lead
- Volatile organic compounds

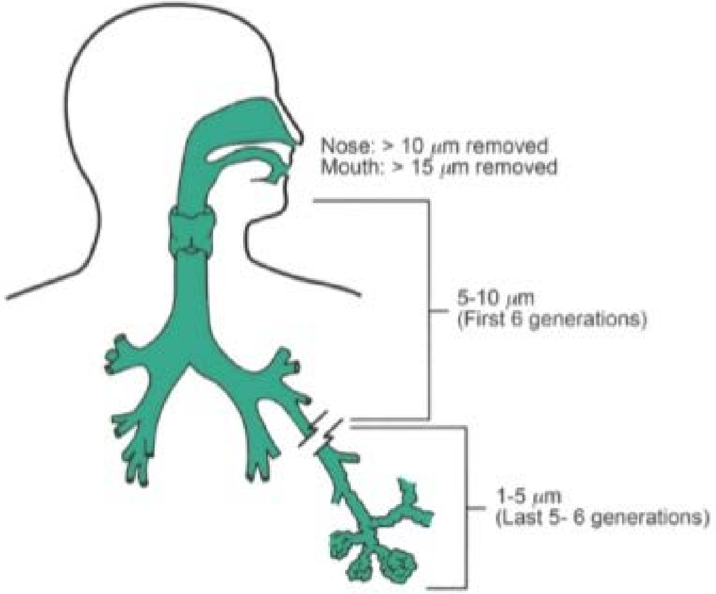
Diesel powered machinery generate diesel particulates

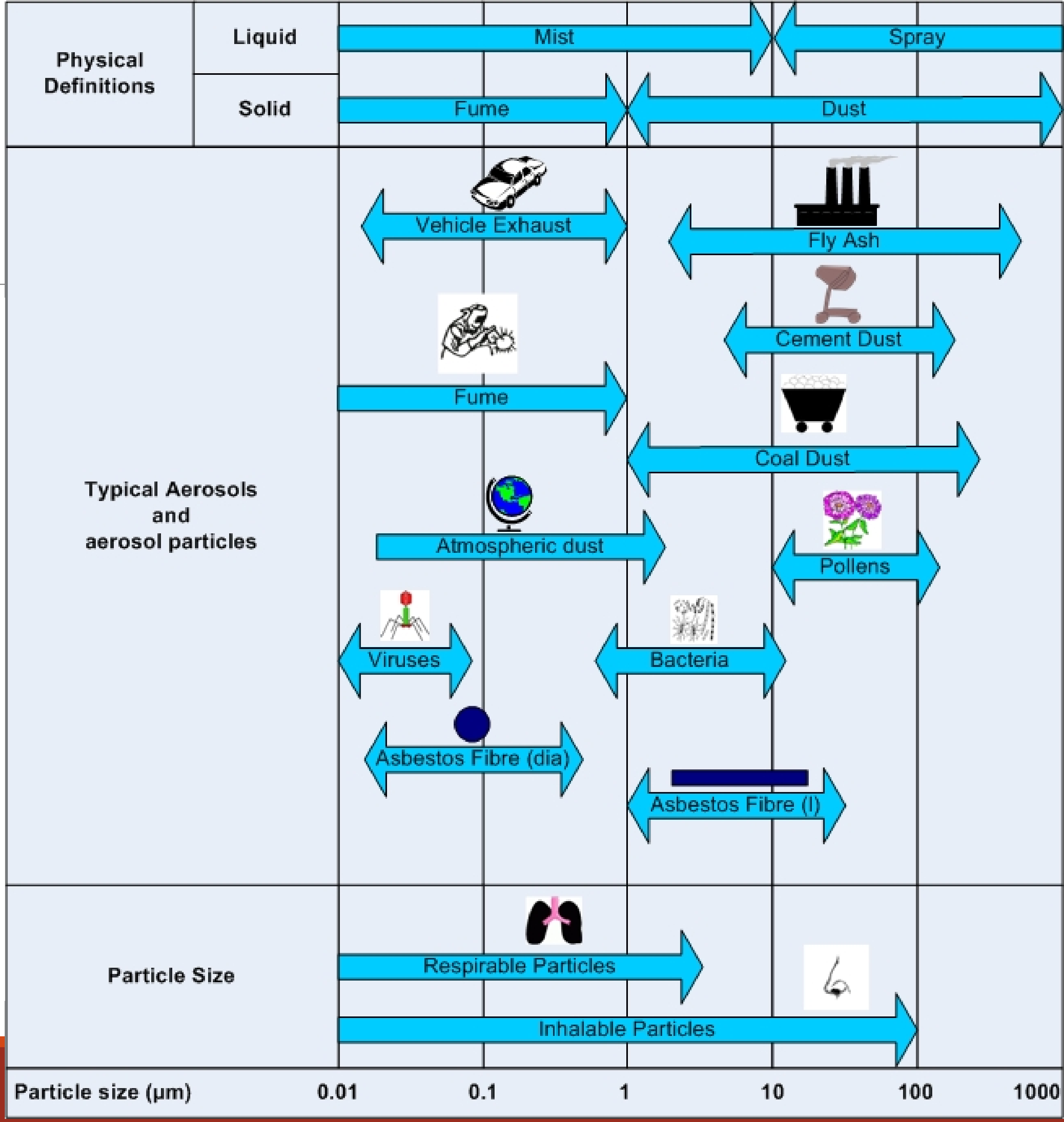
Microbial bioaerosols

Chemicals including isocyanates (used for roof bolt glues)

Particle Size

The effect of aerosol particle size on the site of preferential deposition in the airways





Spectrum of Coal Mine Dust Lung Disease (CMDLD)

Coal worker's pneumoconiosis (CWP)

- **Classic CWP: simple and complicated CWP (progressive massive fibrosis- PMF)**
- Rapidly progressive pneumoconiosis
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- Lung cancer
- Caplans syndrome – Rheumatoid CWP

Classic CWP

Parenchymal lung disease caused by CMD exposure.

Typically diagnosed after 10 year history of exposure to CMD. Shorter if intense exposure.

- Simple CWP: Characterised by small opacities < 10 mm, mostly in the upper lobes. Worker usually asymptomatic and may detected by screening.
- Complicated CWP: more than one nodule $\geq$ 10 mm in size.
- Progressive massive fibrosis (term often used interchangeably with complicated CWP): Lesions become larger, coalesce and cause volume loss and emphysema.
- Dyspnoea of varying severity, productive cough sometimes with black sputum (melanoptysis)

Risk of developing CWP and disease progression primarily associated with dose of CMD exposure, dust characteristics and age.

Pathogenesis

Direct cytotoxic effect of CMD particles and the release of pro-inflammatory and pro-fibrotic mediators by cells responding to particles.

Dust accumulates initially in walls of respiratory bronchioles, leading to collections of dust-laden macrophages in airway walls especially at bifurcations.

Release of inflammatory mediators leads to fibrous tissue deposition which later shrink leading to distortion of local lung structures.

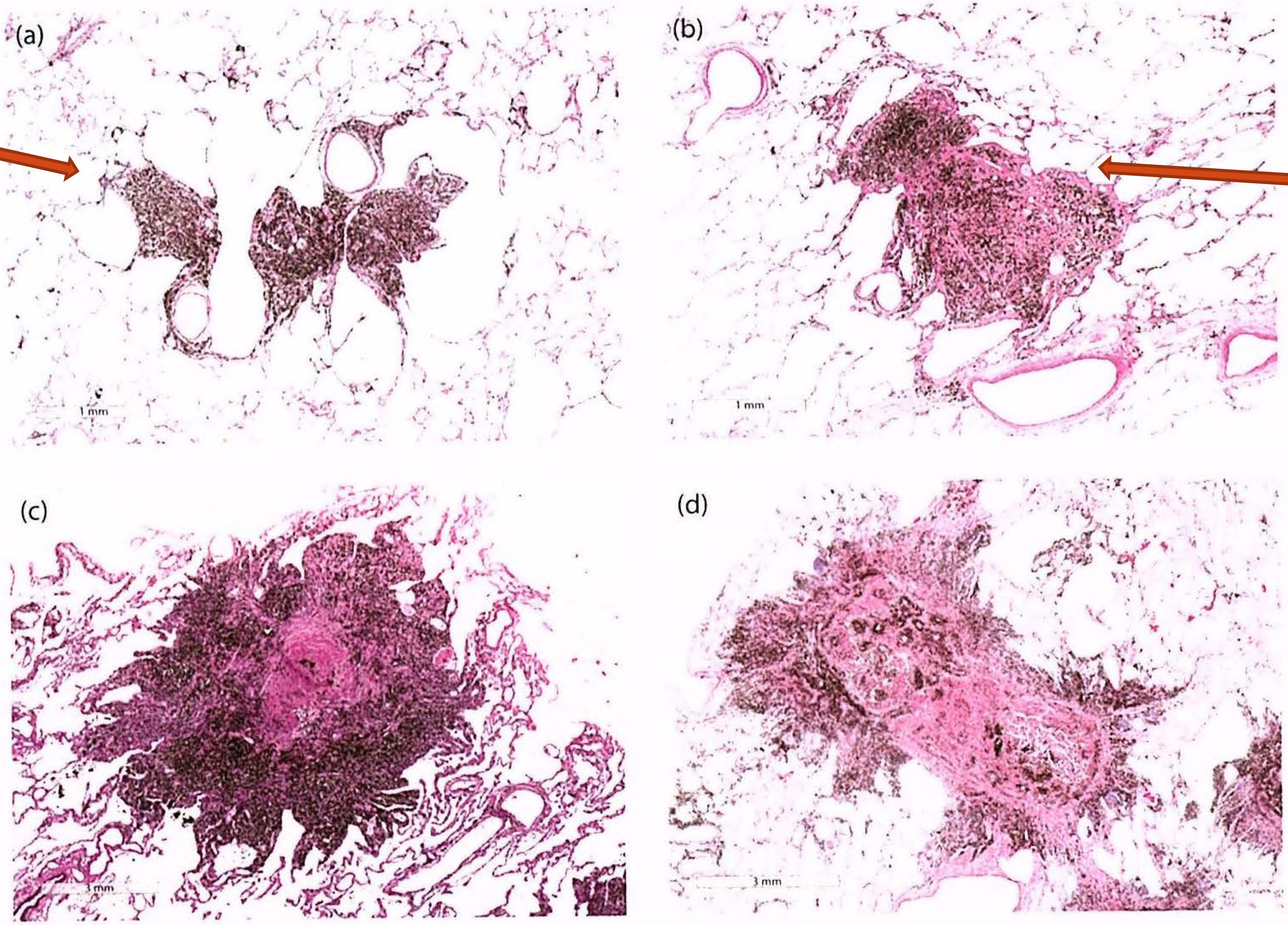
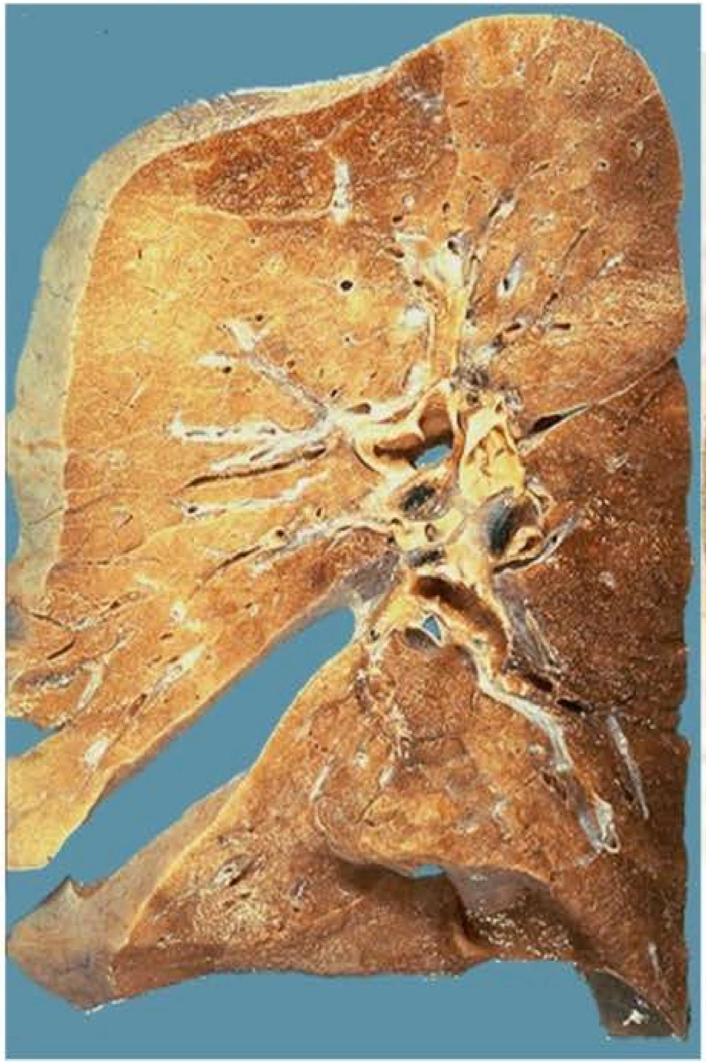


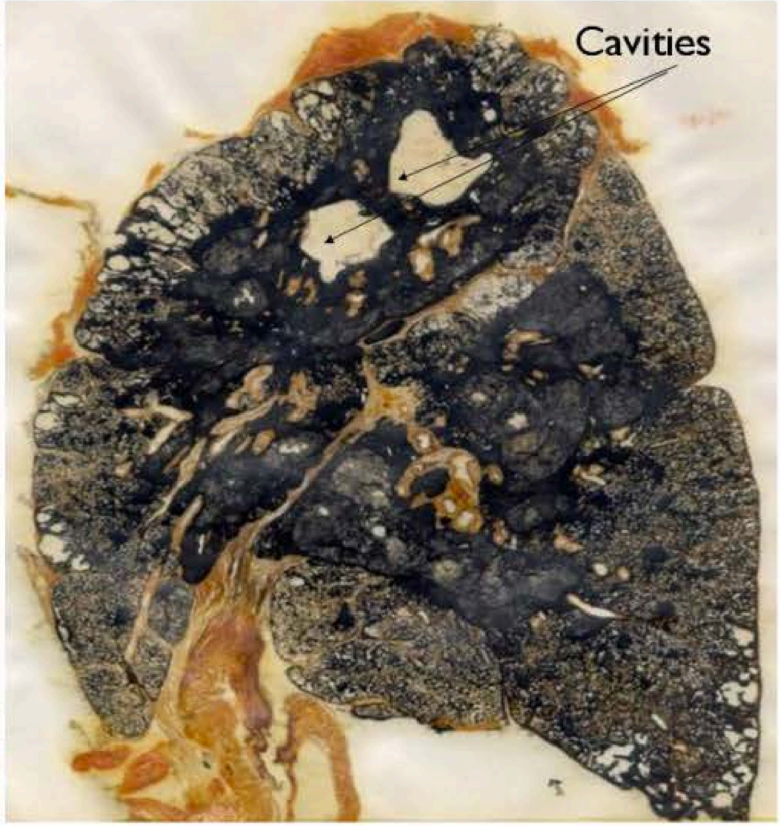
FIGURE 19.1 (a) Classic coal dust macule in the wall of a respiratory bronchiole and surrounded by a rim of centriacinar emphysema. The macule is composed of dust-containing macrophages in a reticulin stroma, with minimal fibrosis. (b) Classic coal dust nodule adjacent to a blood vessel in the interlobular septum. The nodule is composed of dust-laden macrophages within a fibrotic stroma. The emphysema adjacent is called scar emphysema. (c) A larger dust nodule with a central silicotic component. The centre is composed of concentrically arranged collagen fibres, and can be shown to contain silica with polarizing microscopy. (d) Small lesion with features of progressive massive fibrosis (PMF). In this example, the lesion has formed from the fusion of two dust nodules, one that appears silicotic. There is central necrosis with cholesterol clefts. The adjacent lung shows scar emphysema. A larger lesion of PMF is shown in Figure 19.3a.

Ref: Parkes' Occupational Lung Disorders, 4th Ed

Normal Simple CWP PMF



Coal Workers' Pneumoconiosis (CWP)



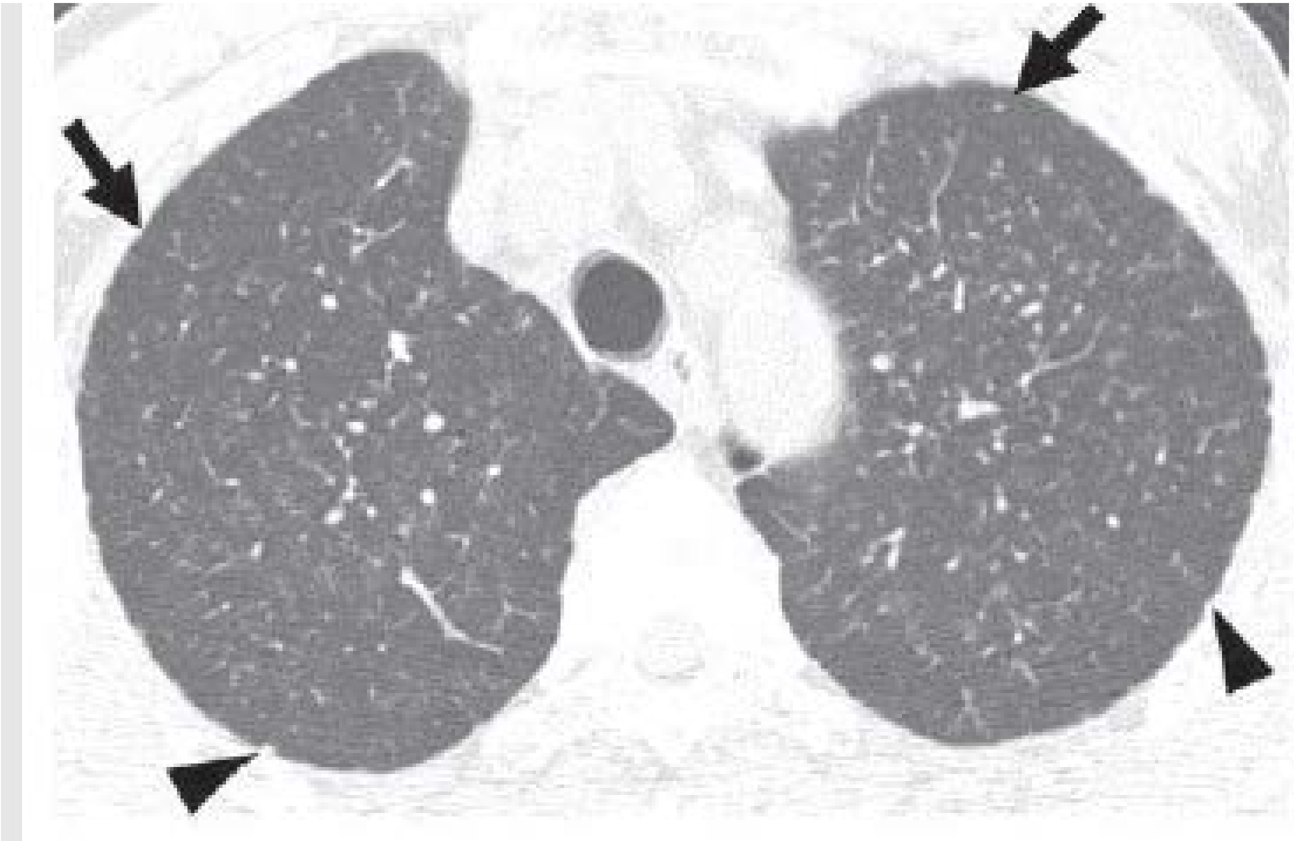
Progressive massive fibrosis
Complicated pneumoconiosis

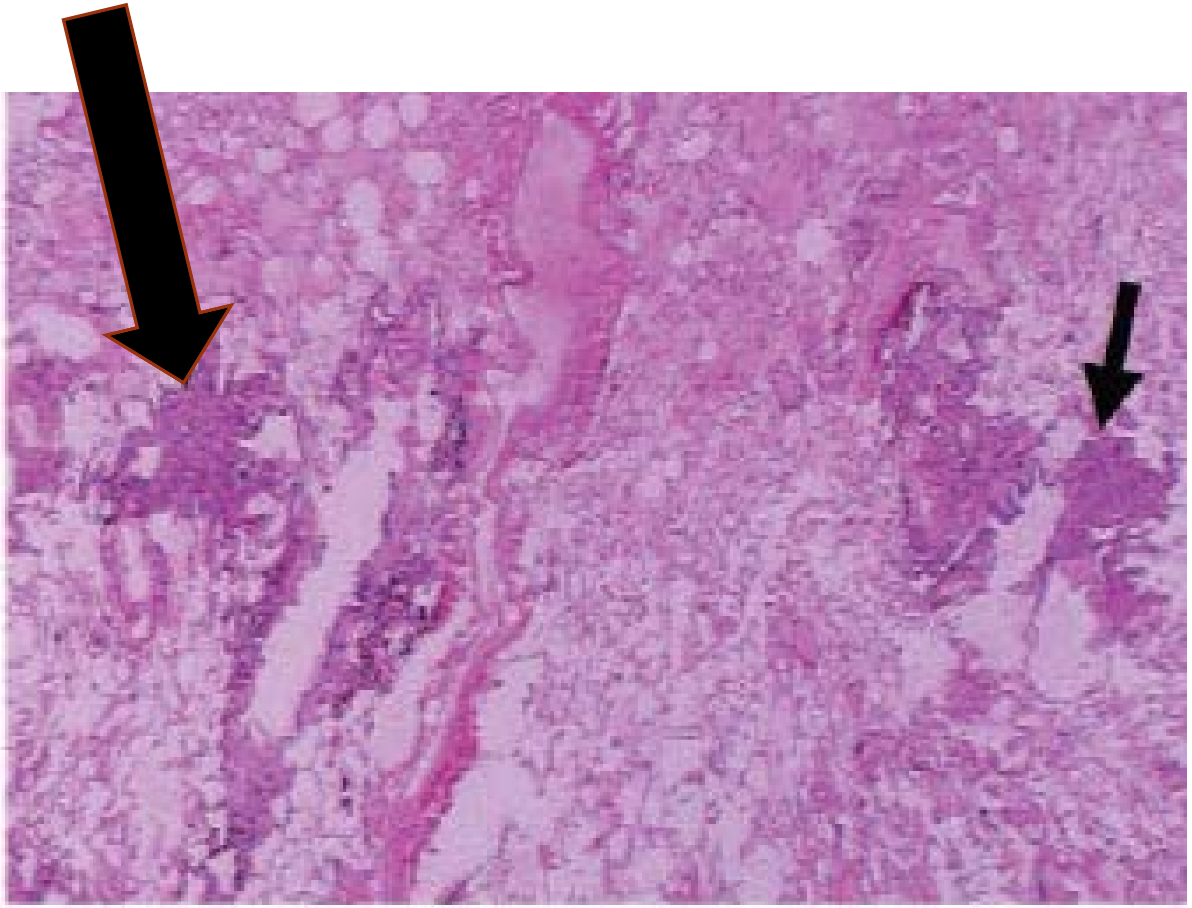
Source: NIOSH Coal Workers' X-ray Surveillance Program (CWXSP)

DIFFUSE NODULES

NUMEROUS

Coal macule: dust-laden macrophages within wall of respiratory bronchiole with reticulin and collagen

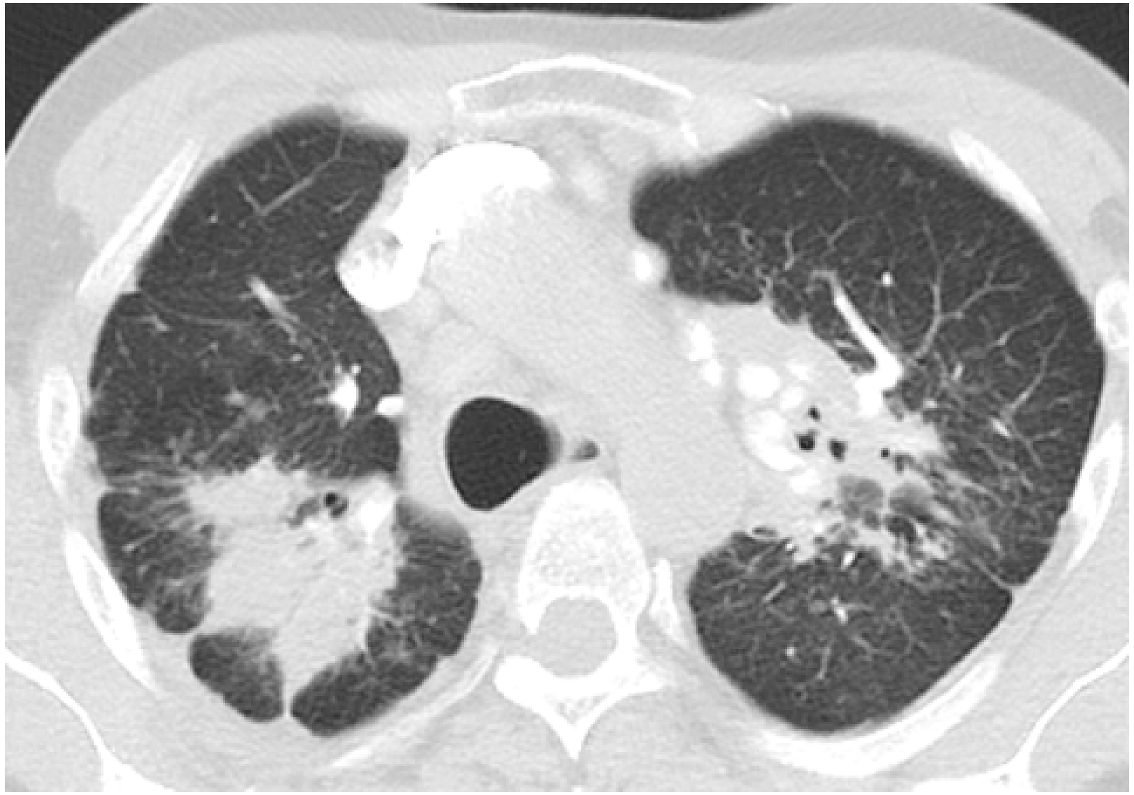




Progressive Massive Fibrosis

Case courtesy of Dr Ian Bickle, Radiopaedia.org, rID: 46086

Progressive Massive Fibrosis



Epidemiology

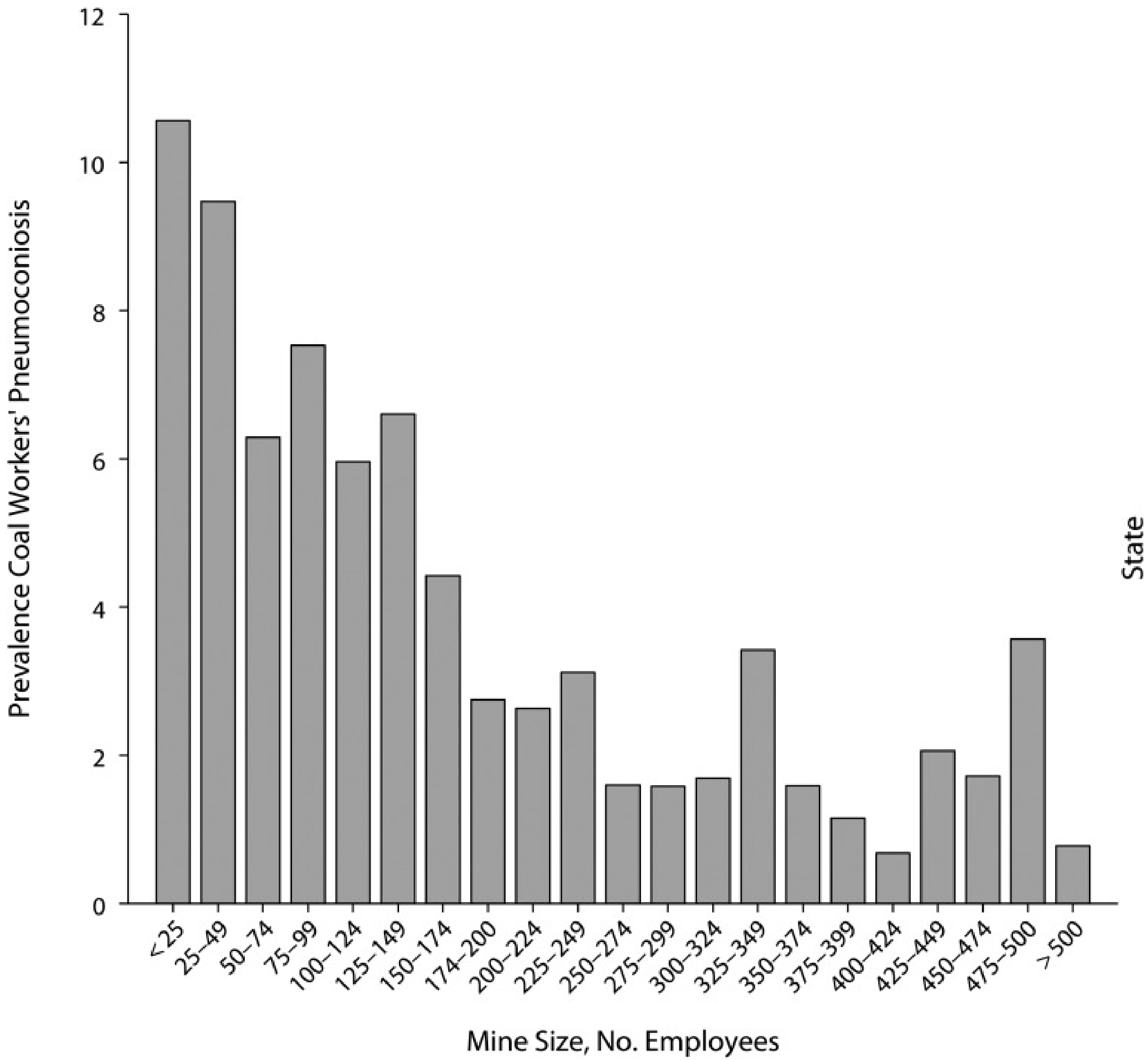
Pathological studies:

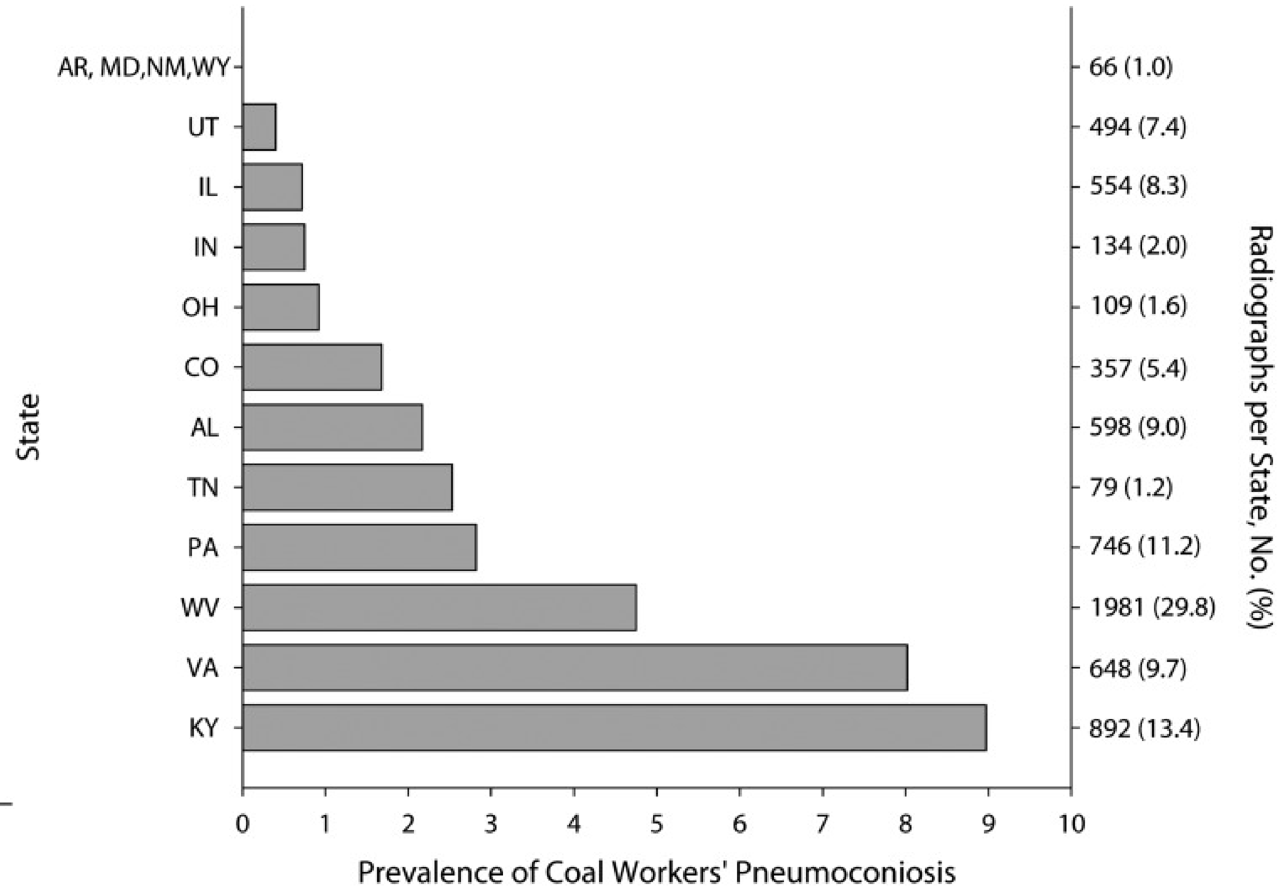
US National Coal Mine Workers Autopsy Study: Miners prior to introduction of dust standards in 1969 82% with coal macules, 10.3% with PMF. Miners worked exclusively after 1969 58% coal macules, 1.2% with PMF.

Radiological surveillance:

China 6% (Mo et al, 2014)

USA- Decline from 6.5% in 1970s after introduction of dust control regulations to 2.1% in 1990s, recent increase to 3.2%





Laney et al, 2012

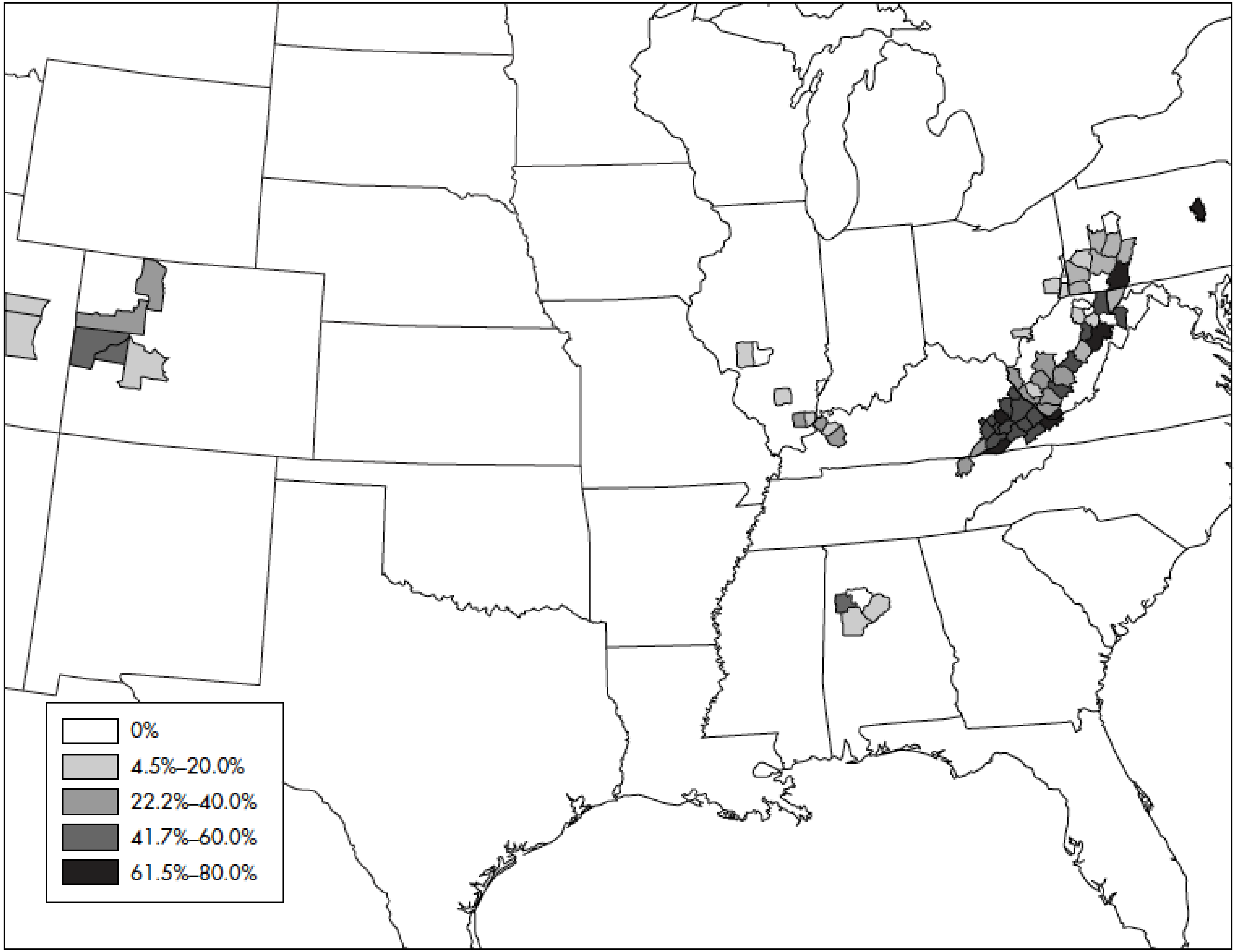


Figure 1 Proportion of evaluated miners with rapidly progressive coal workers' pneumoconiosis by county (not shown are counties with fewer than five miners evaluated).

Occup Environ Med 2005;**62**:670–674.

Health surveillance

Screening programs are crucial for monitoring the health of coal workers to identify individuals with early-stage disease and prevent progression from mild asymptomatic disease to PMF.

Identification of abnormal findings should lead to assessment by specialist respiratory and/or occupational physician

- Establish diagnosis
- Determine severity of disease
- Provide recommendations to worker regarding risk related to further exposure
- Communication with employer/regulator regarding potential deficiencies in control measures.

WHO recommends assessment before commencing work, annual symptom questionnaire and spirometry, and follow-up chest x-rays every 2- 5 years.

Symptom assessment

Standardised respiratory symptoms questionnaire such as American Thoracic Society respiratory questionnaire or British Medical Research Council (MRC) Respiratory Questionnaire 1986

Standardised occupational history questionnaire including list of all jobs, description of all duties and potential exposures and protective equipment required to use.

Chest radiography - ILO classification

International
Labour
Organization

The purpose is to describe and codify radiographic abnormalities of pneumoconioses in a simple, systematic, and reproducible manner. Describes the nature and extent of features associated with different pneumoconioses.

Classification System includes the Guidelines and two sets of standard films. <u>The standard films represent different types and severity of abnormalities and are used for comparison to subject films during the classification process.</u>

In the US NIOSH requires reviews of chest radiographs to be “B readers”. This is a proficiency program to provide a pool of qualified readers capable of accurately using the ILO system.

Examinations are offered monthly at NIOSH’s Appalachian Laboratory for Occupational Safety and Health located in Morgantown, West Virginia. Each B Reader is required to be re-examined every four years.

ILO classification

1. Grade quality of film

2. Categorise small opacities (< 10mm) according to shape and size:
   - Rounded opacities: p (up to 1.5 mm), q (1.5-3 mm), or r (3-10 mm)
   - Irregular opacities: by width as s, t, or u (same sizes as for small rounded opacities)

3. Profusion (frequency/concentration of opacities)
   - Classified on a 4-point major category scale (0 – 3), with each major category divided into three, giving a 12-point scale between 0/- and 3/4.

Category 0	0/-	0/0	0/1
Category 1	1/0	1/1	1/2
Category 2	2/1	2/2	2/3
Category 3	3/2	3/3	3/4

ILO standards: Profusion

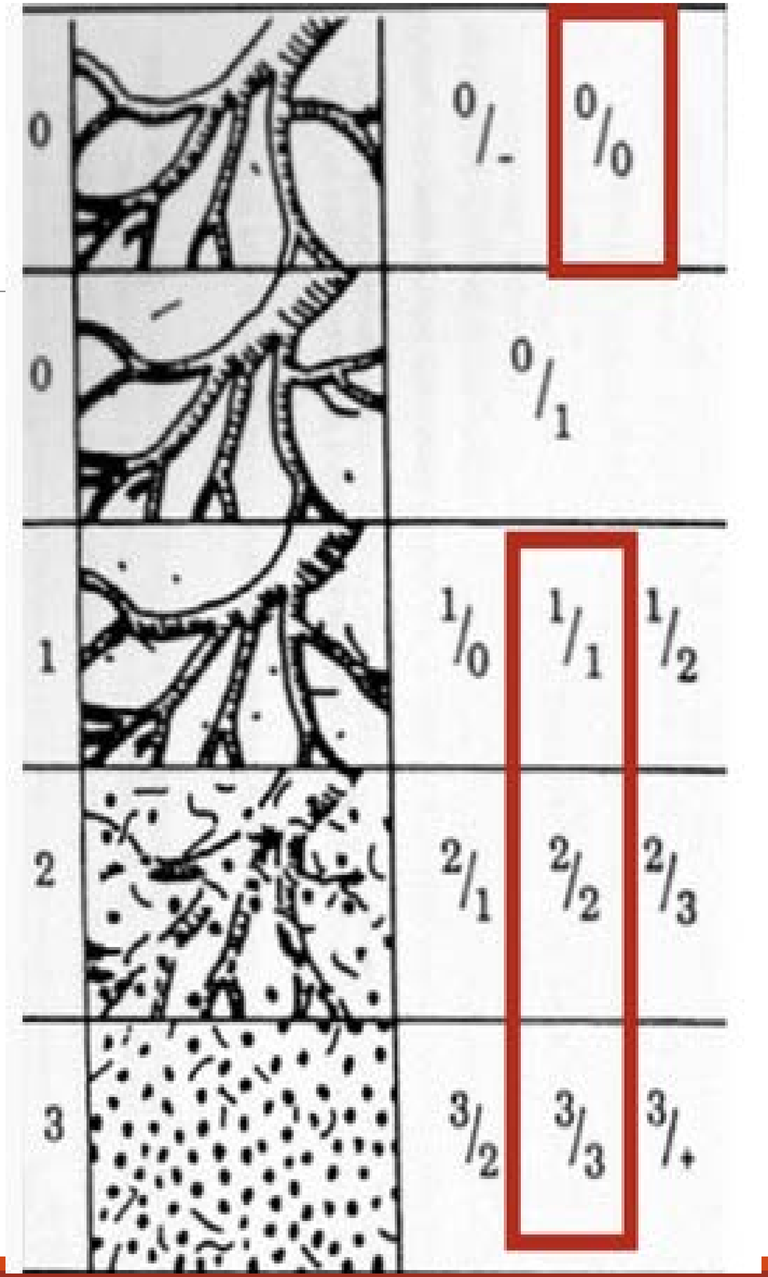
Clearly Normal: 0/0

Normal after consideration of grade 1: 0/1

Opacities not obliterating vascular markings: Category 1

Opacities begin to obliterate vascular markings: Category 2

Opacities completely obliterating vascular markings Category 3



With thanks to Dr Katrina Newbigin,
Wesley Medical Imaging

ILO classification

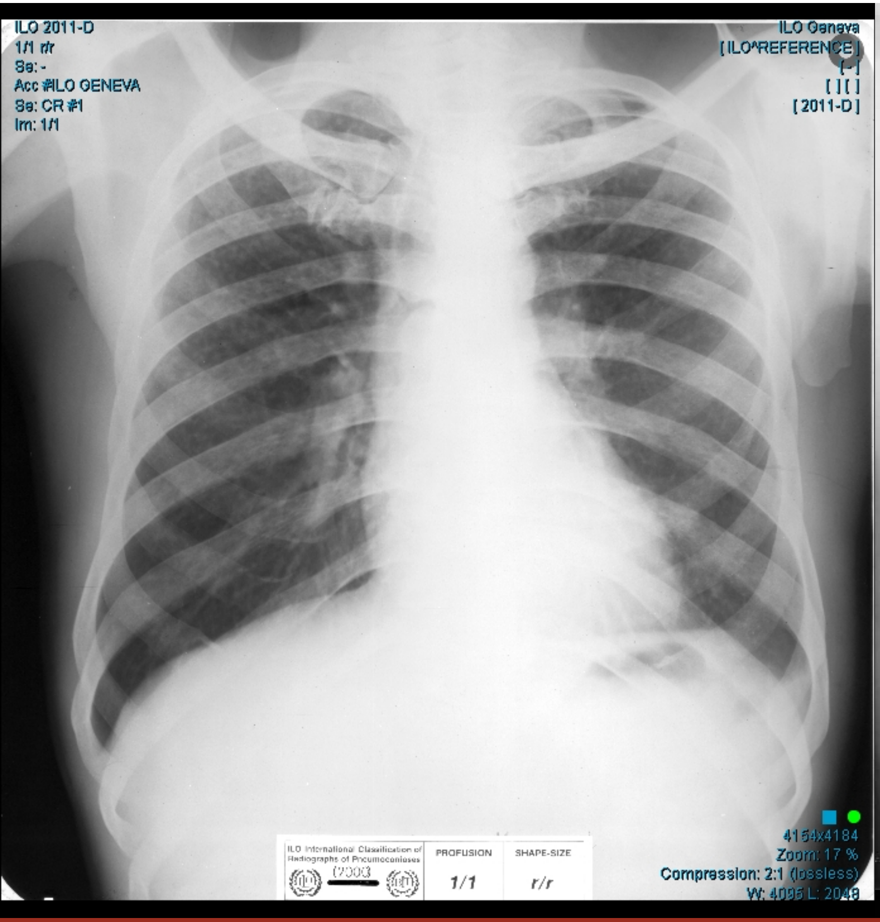
4. Large opacities (maximum diameter $\geq$ 10 mm consistent with PMF) super imposed on background of small nodules

Category A	One or more large opacities whose combined dimension does not exceed 5 cm
Category B	One or more large opacities whose combined dimension exceeds 5 cm but does not exceed the equivalent area of the right upper lung zone
Category C	An area more than that of the right upper lobe is involved

5. Location

6. Pleural and other abnormalities

ILO standard radiographs



International Labour Organization

DATE OF RADIOGRAPH (mm-dd-yyyy)

National Institute for Occupational Safety and Health
1095 Willowdale Road, MS LB208
Morgantown, WV 26505
FAX: 304-285-6058

REV. 01/2015

EXAMINEE'S Social Security Number

Full SSN is optional, last 4 digits are required.

TYPE OF READING

A ☐ B ☐ F ☐

FACILITY Number - Unit Number

Note: Please record your interpretation of a single radiograph by placing an "x" in the appropriate boxes on this form. Classify all appearances described in the ILO International Classification of Radiographs of Pneumoconiosis or Illustrated by the ILO Standard Radiographs. Use symbols and record comments as appropriate.

1. IMAGE QUALITY

1 2 3 U/R

(If not Grade 1, mark all boxes that apply)

☐ Overexposed (dark)	☐ Improper position	☐ Underinflation
☐ Underexposed (light)	☐ Poor contrast	☐ Mottle
☐ Artifacts	☐ Poor processing	☐ Other (please specify)

2A. ANY CLASSIFIABLE PARENCHYMAL ABNORMALITIES? YES ☐ Complete Sections 2B and 2C NO ☐ Proceed to Section 3A

2B. SMALL OPACITIES

a. SHAPE/SIZE

PRIMARY		SECONDARY	
p	s	p	s
q	t	q	t
r	u	r	u

b. ZONES

	R	L
UPPER	☐	☐
MIDDLE	☐	☐
LOWER	☐	☐

c. PROFUSION

0/-	0/0	0/1
1/0	1/1	1/2
2/1	2/2	2/3
3/2	3/3	3/+

2C. LARGE OPACITIES

SIZE O A B C Proceed to Section 3A

3A. ANY CLASSIFIABLE PLEURAL ABNORMALITIES? YES ☐ Complete Sections 3B, 3C NO ☐ Proceed to Section 4A

3B. PLEURAL PLAQUES *(mark site, calcification, extent, and width)*

Chest wall	Site	Calcification
In profile	O R L	O R L
Face on	O R L	O R L
Diaphragm	O R L	O R L
Other site(s)	O R L	O R L

Extent (chest wall; combined for in profile and face on)
Up to 1/4 of lateral chest wall = 1
1/4 to 1/2 of lateral chest wall = 2
> 1/2 of lateral chest wall = 3

O R 1 2 3 — O L 1 2 3

Width (in profile only)
(3mm minimum width required)
3 to 5 mm = a
5 to 10 mm = b
> 10 mm = c

O R a b c — O L a b c

3C. COSTOPHRENIC ANGLE OBLITERATION R L Proceed to Section 3D NO ☐ Proceed to Section 4A

3D. DIFFUSE PLEURAL THICKENING *(mark site, calcification, extent, and width)*

Chest wall	Site	Calcification
In profile	O R L	O R L
Face on	O R L	O R L

Extent (chest wall; combined for in profile and face on)
Up to 1/4 of lateral chest wall = 1
1/4 to 1/2 of lateral chest wall = 2
> 1/2 of lateral chest wall = 3

O R 1 2 3 — O L 1 2 3

Width (in profile only)
(3mm minimum width required)
3 to 5 mm = a
5 to 10 mm = b
> 10 mm = c

O R a b c — O L a b c

4A. ANY OTHER ABNORMALITIES? YES ☐ Complete Sections 4B, 4C, 4D, 4E NO ☐ Complete physician info and sign form.

5. PHYSICIAN'S Social Security Number*

Full SSN is optional, last 4 digits are required.

READER'S INITIALS

DATE OF READING (mm-dd-yyyy)

SIGNATURE

PRINTED NAME (LAST, FIRST MIDDLE)

STREET ADDRESS

CITY

STATE

ZIP CODE

Screening: CXR vs CT

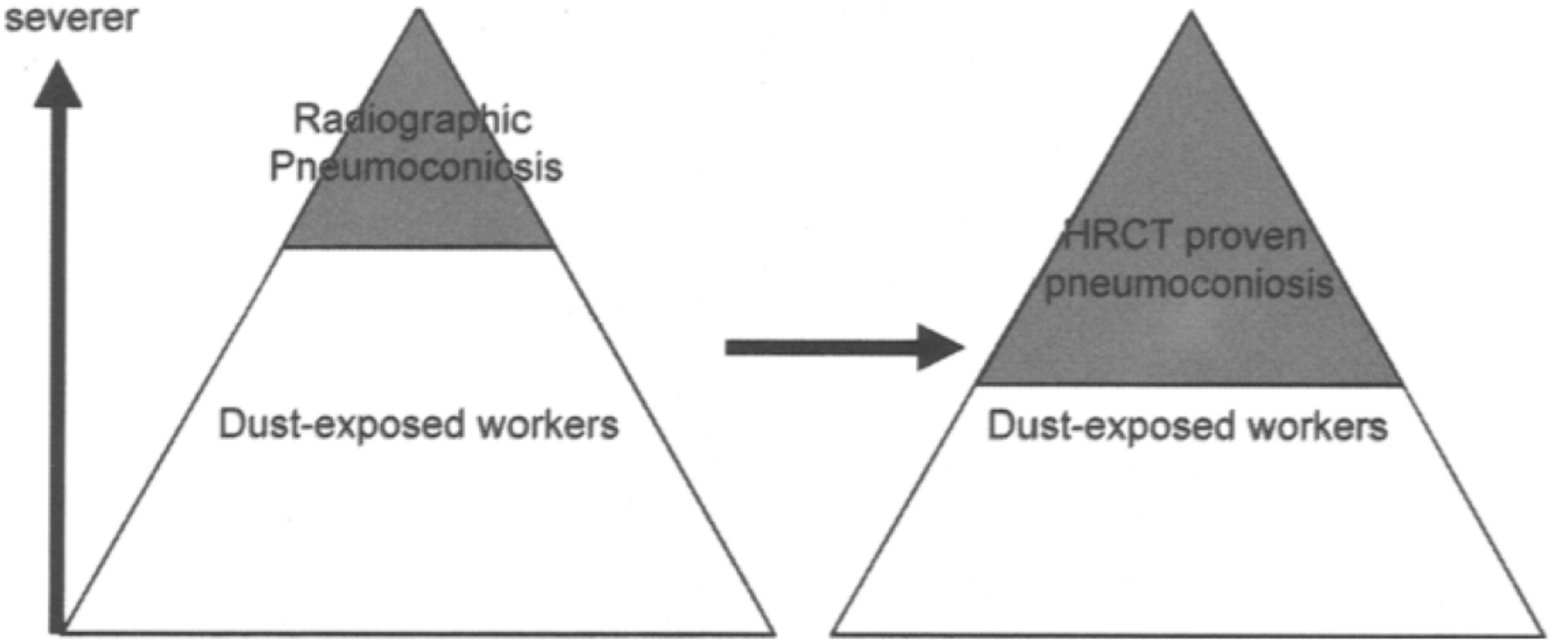
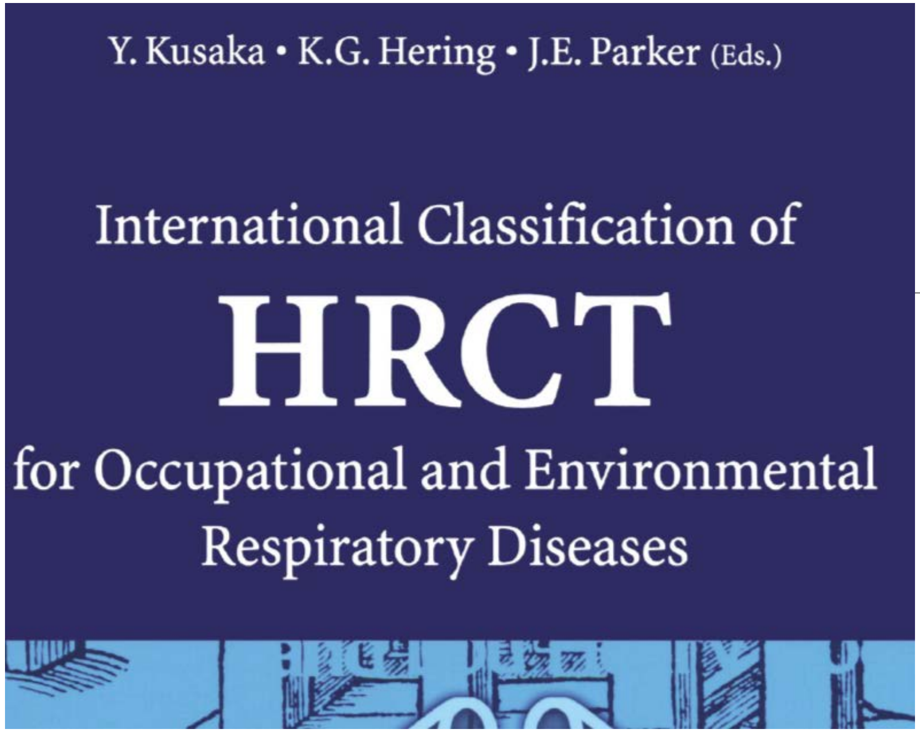
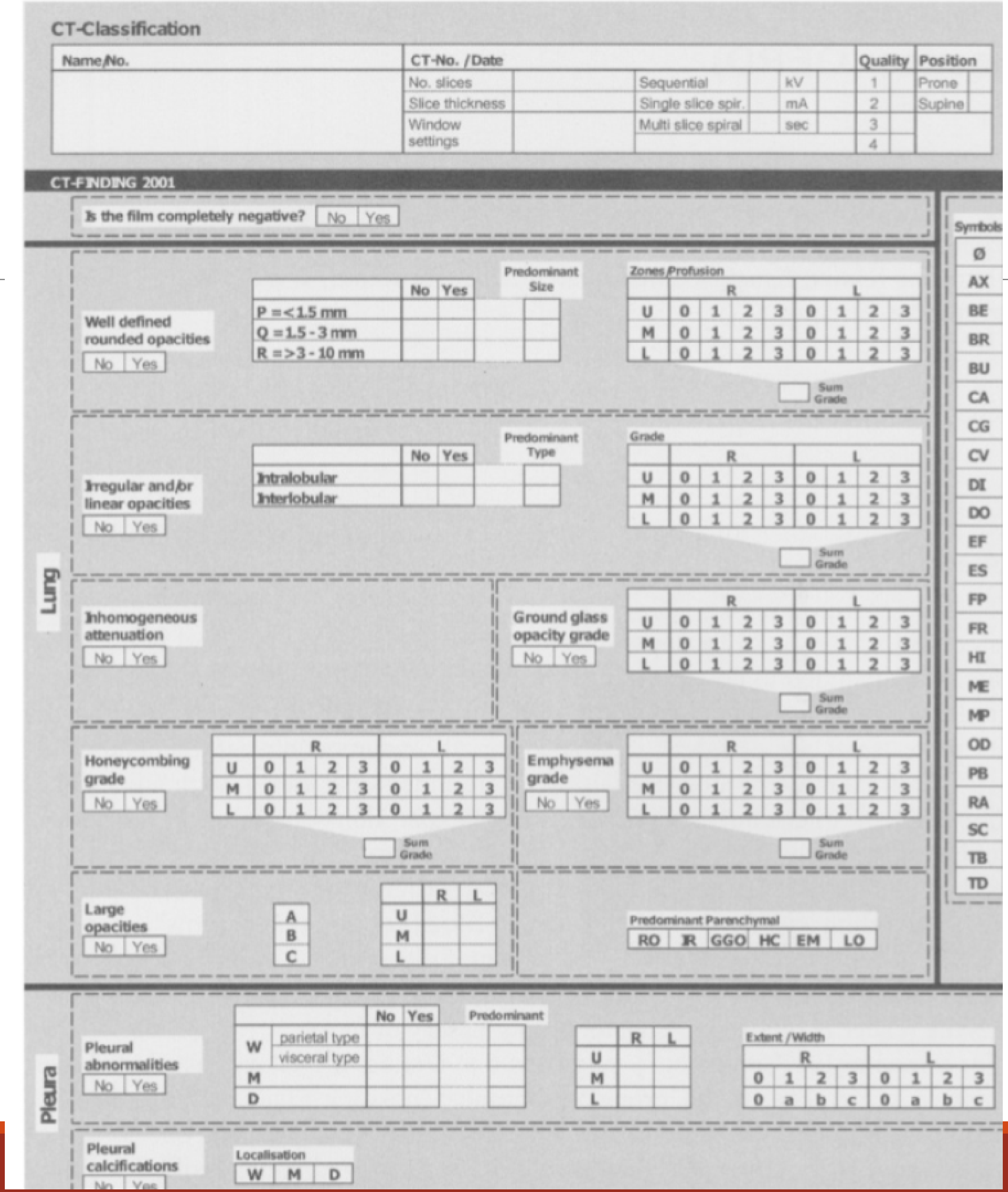


Fig.5.1. Introducing HRCT into screening for pneumoconioses enables an earliest preventive intervention to dust exposed workers. Note severity of pneumoconiosis progresses upward usually as latent period and amount of dust-exposure increases





CT-Classification

Name/No.	CT-No. /Date						Quality	Position
	No. slices		Sequential		kV		1	Prone
	Slice thickness		Single slice spir.		mA		2	Supine
	Window settings		Multi slice spiral		sec		3	
							4	

CT-FINDING 2001

Is the film completely negative? No Yes

Lung

Well defined rounded opacities No Yes

	No	Yes	Predominant Size
P =<1.5 mm			
Q =1.5 - 3 mm			
R =>3 - 10 mm			

Zones/Profusion

	R				L			
U	0	1	2	3	0	1	2	3
M	0	1	2	3	0	1	2	3
L	0	1	2	3	0	1	2	3

Sum Grade

Irregular and/or linear opacities No Yes

	No	Yes	Predominant Type
Intralobular			
Interlobular			

Grade

	R				L			
U	0	1	2	3	0	1	2	3
M	0	1	2	3	0	1	2	3
L	0	1	2	3	0	1	2	3

Sum Grade

Inhomogeneous attenuation No Yes

Ground glass opacity grade No Yes

	R				L			
U	0	1	2	3	0	1	2	3
M	0	1	2	3	0	1	2	3
L	0	1	2	3	0	1	2	3

Sum Grade

Honeycombing grade No Yes

	R				L			
U	0	1	2	3	0	1	2	3
M	0	1	2	3	0	1	2	3
L	0	1	2	3	0	1	2	3

Sum Grade

Emphysema grade No Yes

	R				L			
U	0	1	2	3	0	1	2	3
M	0	1	2	3	0	1	2	3
L	0	1	2	3	0	1	2	3

Sum Grade

Large opacities No Yes

A
B
C

	R	L
U		
M		
L		

Predominant Parenchymal

RO	IR	GGO	HC	EM	LO

Symbols: Ø, AX, BE, BR, BU, CA, CG, CV, DI, DO, EF, ES, FP, FR, HI, ME, MP, OD, PB, RA, SC, TB, TD

Pleura

Pleural abnormalities No Yes

		No	Yes	Predominant
W	parietal type			
	visceral type			
M				
D				

	R	L
U		
M		
L		

Extent / Width

R				L			
0	1	2	3	0	1	2	3
0	a	b	c	0	a	b	c

Pleural calcifications No Yes

Localisation

W	M	D

J OCCUP HEALTH 2009; 51: 210–222

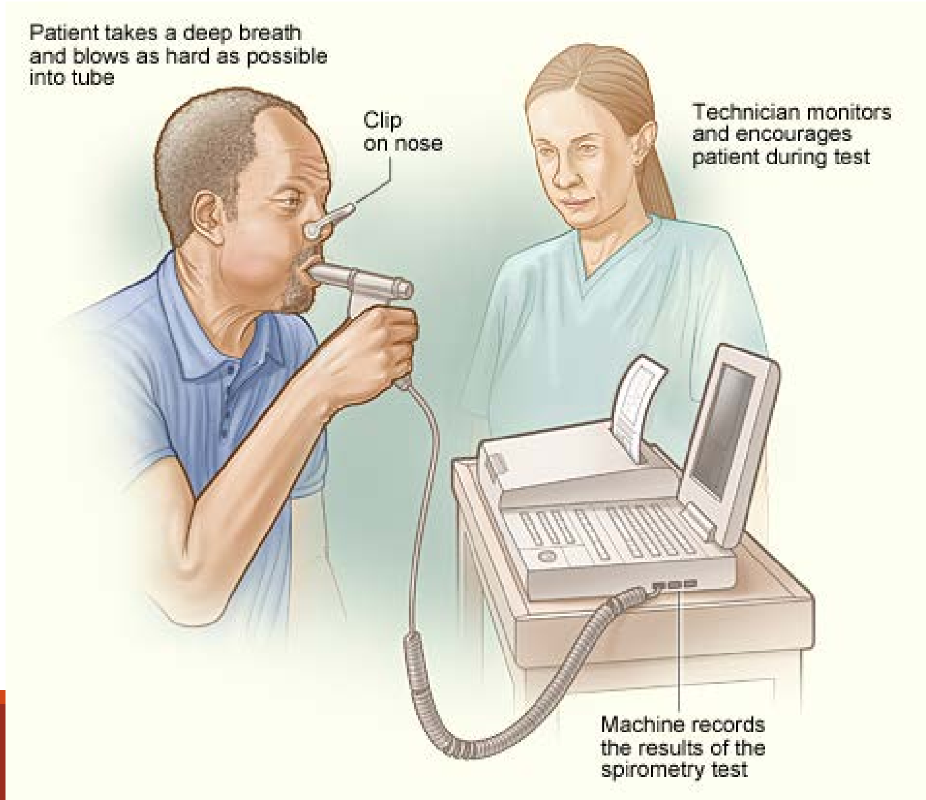
Spirometry

Aim to detect abnormal lung function that may indicate the presence of a coal mine dust lung disease.

Identify workers that require further specialist evaluation and other investigations

Assess the severity of disease

Assess lung function changes over time



SERIES "ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING"
Edited by V. Brusasco, R. Crapo and G. Viegi
Number 2 in this Series

Standardisation of spirometry

Equipment

Test procedures

Within and between maneuver evaluation:

- Each session must have the goal of obtaining at least 3 acceptable spirograms with 2 repeatable forced expiratory maneuvers.

Eur Respir J 2005; 26: 319–338

TABLE 5 Summary of within- and between-manoeuvre acceptability criteria

Within-manoeuvre criteria

Individual spirograms are "acceptable" if
- They are free from artefacts [3]
  - Cough during the first second of exhalation
  - Glottis closure that influences the measurement
  - Early termination or cut-off
  - Effort that is not maximal throughout
  - Leak
  - Obstructed mouthpiece
- They have good starts
  - Extrapolated volume <5% of FVC or 0.15 L, whichever is greater
- They show satisfactory exhalation
  - Duration of ⩾6 s (3 s for children) or a plateau in the volume–time curve or
    If the subject cannot or should not continue to exhale

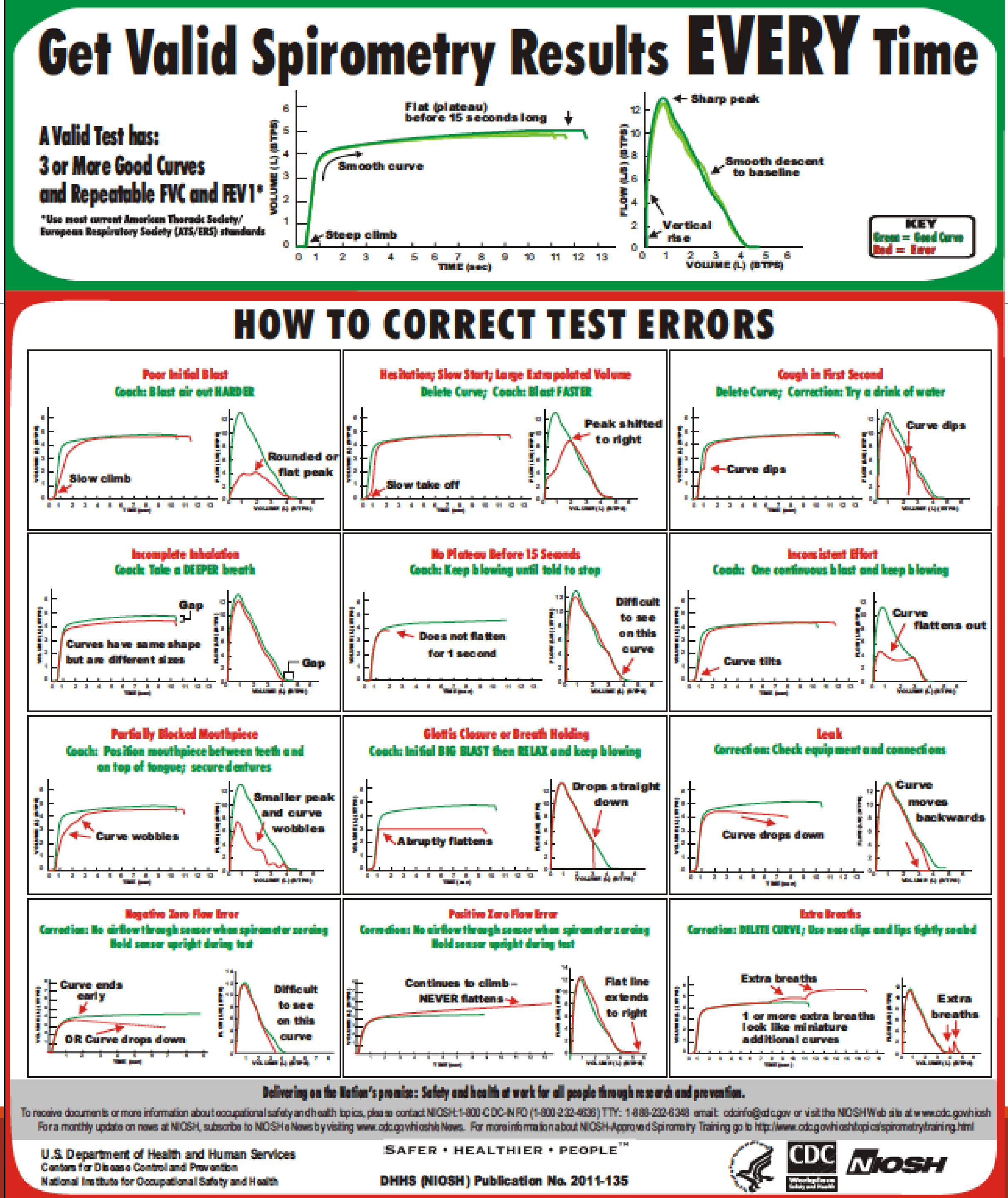
Between-manoeuvre criteria

After three acceptable spirograms have been obtained, apply the following tests
- The two largest values of FVC must be within 0.150 L of each other
- The two largest values of FEV_1 must be within 0.150 L of each other

If both of these criteria are met, the test session may be concluded

If both of these criteria are not met, continue testing until
- Both of the criteria are met with analysis of additional acceptable spirograms or
- A total of eight tests have been performed (optional) or
- The patient/subject cannot or should not continue

Save, as a minimum, the three satisfactory manoeuvres


Get Valid Spirometry Results EVERY Time
A Valid Test has:
3 or More Good Curves
and Repeatable FVC and FEV1*
*Use most current American Thoracic Society/European Respiratory Society (ATS/ERS) standards
Flat (plateau) before 15 seconds long
Smooth curve
Steep climb
VOLUME (L) (BTPS)
TIME (sec)
Sharp peak
Smooth descent to baseline
Vertical rise
FLOW (L/S) (BTPS)
VOLUME (L) (BTPS)
KEY
Green = Good Curve
Red = Error
HOW TO CORRECT TEST ERRORS
Poor Initial Blast
Coach: Blast air out HARDER
Slow climb
Rounded or flat peak
Hesitation; Slow Start; Large Extrapolated Volume
Delete Curve; Coach: Blast FASTER
Slow take off
Peak shifted to right
Cough in First Second
Delete Curve; Correction: Try a drink of water
Curve dips
Curve dips
Incomplete Inhalation
Coach: Take a DEEPER breath
Gap
Curves have same shape but are different sizes
Gap
No Plateau Before 15 Seconds
Coach: Keep blowing until told to stop
Does not flatten for 1 second
Difficult to see on this curve
Inconsistent Effort
Coach: One continuous blast and keep blowing
Curve tilts
Curve flattens out
Partially Blocked Mouthpiece
Coach: Position mouthpiece between teeth and on top of tongue; secure dentures
Curve wobbles
Smaller peak and curve wobbles
Glottis Closure or Breath Holding
Coach: Initial BIG BLAST then RELAX and keep blowing
Abruptly flattens
Drops straight down
Leak
Correction: Check equipment and connections
Curve drops down
Curve moves backwards
Negative Zero Flow Error
Correction: No airflow through sensor when spirometer zeroing
Hold sensor upright during test
Curve ends early
OR Curve drops down
Difficult to see on this curve
Positive Zero Flow Error
Correction: No airflow through sensor when spirometer zeroing
Hold sensor upright during test
Continues to climb – NEVER flattens
Flat line extends to right
Extra Breaths
Correction: DELETE CURVE; Use nose clips and lips tightly sealed
Extra breaths
1 or more extra breaths look like miniature additional curves
Extra breaths
Delivering on the Nation's promise: Safety and health at work for all people through research and prevention.
To receive documents or more information about occupational safety and health topics, please contact NIOSH: 1-800-CDC-INFO (1-800-232-4636) TTY: 1-888-232-6348 email: cdcinfo@cdc.gov or visit the NIOSH Web site at www.cdc.gov/niosh
For a monthly update on news at NIOSH, subscribe to NIOSH eNews by visiting www.cdc.gov/niosh/eNews. For more information about NIOSH-Approved Spirometry Training go to http://www.cdc.gov/niosh/topics/spirometry/training.html
U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
SAFER • HEALTHIER • PEOPLE™
DHHS (NIOSH) Publication No. 2011-135
CDC
NIOSH

Official American Thoracic Society Technical Standards: Spirometry in the Occupational Setting

Carrie A. Redlich, Susan M. Tarlo, John L. Hankinson, Mary C. Townsend, William L. Eschenbacher, Susanna G. Von Essen, Torben Sigsgaard, and David N. Weissman; on behalf of the American Thoracic Society Committee on Spirometry in the Occupational Setting

Am J Respir Crit Care Med Vol 189, Iss 8, pp 984–994, Apr 15, 2014

SERIES "ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING"
Edited by V. Brusasco, R. Crapo and G. Viegi
Number 5 in this Series

Interpretative strategies for lung function tests

Eur Respir J 2005; 26: 948–968

Spirometry interpretation

Determination of what is considered an abnormal result is particularly important in the occupational setting.

Although more difficult to calculate, recommendation is for use of 5th percentile of lower limit of normal (LLN) rather than fixed cut offs such as 80% predicted for FEV1 and FVC, or 0.70 for FEV1/FVC ratio.

The lower limit of normal (LLN) is taken to be equal to the 5th percentile of a healthy, non-smoking population, using a specific reference range such as GLI or NHANES III.

In the workplace setting, fixed values will result in false-negative results for younger workers and false-positive results in older workers.

Evaluation of excessive loss of lung function over time is less well defined. Approximately greater than 15% decline from baseline FEV1 (plus expected age related decline). Refer to ATS Standards for Spirometry in the Occupational Setting, 2014

Surveillance data

6373 US miners – 13.1% abnormal spirometric findings

ILO category 0 – 12.5% abnormal results

ILO category 1 – 24.9%

ILO category 2 and 3 – 28.9%

PMF – 40% (Wang et al, 2013)

Medical management

No specific treatment for CWP or CMDLD

If working, limit additional exposure by assessment of need for workplace removal or reassignment to reduce risk of dust exposure. May be worker reluctance.

Treatment of airflow obstruction with bronchodilator therapy

Smoking cessation, vaccinations

Pulmonary rehabilitation

Regular monitoring after exposure to CMD, radiologically and with lung function. Every 2-5 years.

Lung transplantation for end-stage disease may be considered

Resources

US Department of Labor - Black Lung Disability Evaluations and Claims Training for Medical Examiners: https://www.publichealthlearning.com/course/view.php?id=94#section-2

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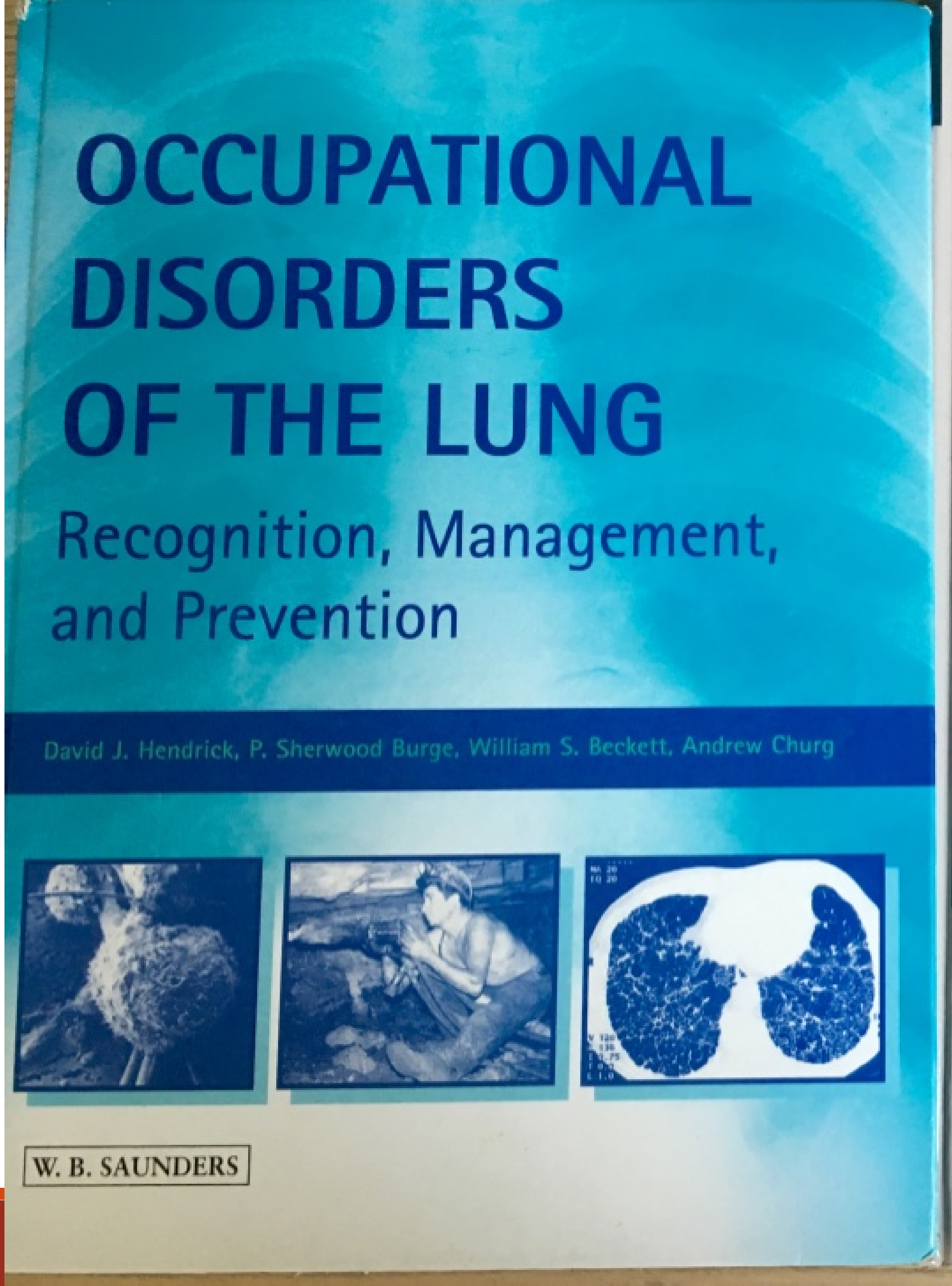
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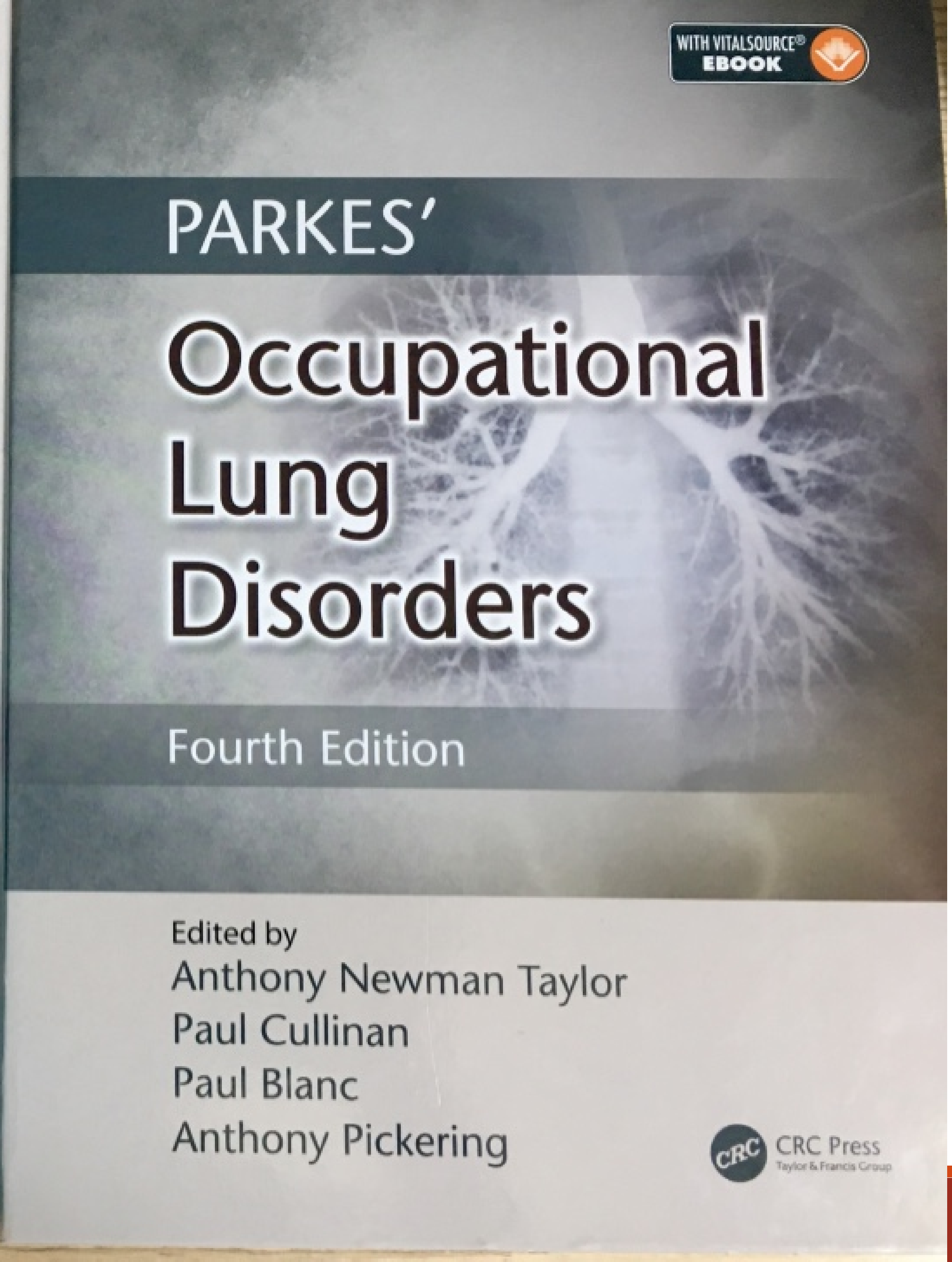
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