The spectrum of coal mine dust lung diseases (CMDLD)

Deborah H Yates
Respiratory Physician
St Vincent’s Hospital, Darlinghurst, NSW 2010
Coal mine dust lung diseases (CMDLD): Summary of talk

• Introduction
• A little history
• Classical coal workers pneumoconiosis (CWP)
• Silicosis in CWP
• Dust-related diffuse fibrosis (DDF)
• Chronic bronchitis and emphysema
• Surveillance, early detection and the future
• Conclusions
In South Wales during the past 15 years rather more than 17,000 men have been certified by the Silicosis Medical Board to be suffering from silicosis or pneumoconiosis and have been excluded from their underground work. More than 10,000 of these have been certified in the past three years. There were two mines in South Wales which lost one in every three of their underground workers among those less than 45 years of age at some time during the last 20 years. In South Wales this is an underestimate of the seriousness of the problem presented to the mining industry by a study of the extent of chronic benefits occasioned by pneumoconiosis in this region. Elsewhere in Great Britain the problem is proportionately less serious, but even here the certification of roughly 1,000 men in 15 years presents a problem that is serious enough.

In 1943 a committee was set up by the Minister of Fuel and Power to consider the rehabilitation and treatment of miners in South Wales suffering from silicosis and pneumoconiosis. Among the recommendations of this committee (Ministry of Fuel and Power, 1944) was that more research into the problem was needed. The Medical Research Council was approached, and in 1957 it established a South Wales Pneumoconiosis Research Unit to study the problem of pneumoconiosis and silicosis among South Wales coal-miners. Since then it has been my custom to seek and carry out research with a growing team of medical and other scientists in this Unit. I propose, first, to consider briefly how the present gloom-strewn situation has arisen into a century remarkable for the important advances in industrial health which have been achieved in almost every industry, than to discuss the former investigations of the Medical Research Council into pneumoconiosis in South Wales, and then to outline some of the recent investigations undertaken by the Pneumoconiosis Research Unit and others in South Wales. I shall also discuss the many different theories of the causation of pneumoconiosis and other diseases of the lung, and, finally, I shall consider the part played by the present Unit in these investigations.

Pneumoconiosis other than asbestosis in the UK 2004-2014 (data from HSE)
Revisiting the past...

Pneumoconiosis = fibrosis of the lung due to dust

(pneumo=lung konios = dust (Gk)
Coal mines in England
Back in 1770..... in England
In 1746 James became apprentice to John Walker, a Whitby ship owner whose collier cats or barks transported coal between Newcastle and London - a round trip of about four weeks. Cook sailed on various vessels, including “Freelove”; “Three Brothers”, which saw Cook released from his apprenticeship (1749); in, “The Mary of Whitby”; and “Friendship”, of which he became Mate (1752).
The USA:
Resurgence of CWP
NIOSH surveillance program

- Prevalence of CWP declined after implementation of 1969 Coal Mine Health & Safety Act
- PMF 0.08% between 1995-2000
- Troubling increase in prevalence in miners with > 15 yrs tenure
- Geographical clustering, rapid disease progression
- Likely increased prevalence of silicosis
- Associated with premature mortality
- Coal miners developing disease at a relatively young age and after implementation of regulation

Percentage of examined US miners with CWP 1970-2012
CWP defined as ILO score of small opacities >1/0 or any large opacity

Laney & Weissman J Occup Environ Med 2014; 56: S18-22
Coal workers’ pneumoconiosis
Years of potential life lost (YPLL) before age of 65; USA 1968-2010

Laney & Weissman J Occup Environ Med 2014; 56: S18-22
Coal mine dust lung diseases (CMDLD): a spectrum of lung disorders

- Classical coal workers pneumoconiosis
- Silicosis
- Dust-related diffuse fibrosis
- Mixed dust pneumoconiosis
- Rheumatoid pneumoconiosis (Caplan’s syndrome)
- Chronic bronchitis and emphysema
- Diesel exhaust exposure, nitrogen oxides
- Toxic gases from coalmine fires etc

"The first priority and concern of all in the coal or other mining industry must be the health and safety of its most precious resource – the miner." (Federal Coal Mine Health and Safety Act of 1969, USA, amended 1977.)

W Raymond Parkes: “The term “black lung” is uninformative......and should have no place in medical terminology”.

Diagnosis of CMDLD

• Based on detailed history of exposures
• Need a thorough respiratory history to exclude/include other diseases
• Respiratory symptoms
• Lung imaging
• Pulmonary function testing
• Histopathology
• ? Also novel methods
Diagnosis of disease differs from disablement

- Medical diagnosis
- Impairment
- Disability due to the disease
- Compensation

- Industrial Injuries Advisory Council (UK) established 1950
- Regular review of occupational disorders by expert committee
Dust exposure, dust retention and radiographic change: mechanisms

- Coal dust inhalation releases cytokines including TNF alpha, IL-1, IL-6, superoxides incl catalase
- Oxidative stress plays a role
- Level of bioavailable iron in different mining regions may be important
- Genetic susceptibility likely important
- Inherent capability of lungs to clear dust is good
- Significant redundancy in lung capacity
Mechanisms of lung clearance
Anthracosis

- Anthraco = coal  -osis = condition
- A term usually used to describe the effects of soot inhalation
- Causes black pigmentation of bronchial mucosa or lung parenchyma but NOT associated with structural abnormalities of the tissue
- “Collier stripes”, “Coal tattoos
- Non-specific term; occurs with exposure to many dusts incl wood dusts, TB, smoky fuels
- No respiratory symptoms unless bronchial anthraco-fibrosis develops
Classical coal workers pneumoconiosis: First stage: dust macules

No symptoms; no radiological abnormalities; not classified as CWP
Dust macules/dust retention

- Pure carbon is non-fibrogenic in low doses
- First manifestation of dust retention:

**Dust macules:**

- 0.5-6 mm collection of macrophages
- Distributed principally along the bronchovascular bundles
- Carbon particles seen in macrophages and free in tissue
- Not associated with fibrosis
- Foci of centrilobular emphysema may occur adjacent to carbon particles (= centriacinar emphysema = focal emphysema)
- No symptoms
- No radiological abnormalities on CXR
Pneumoconiosis: radiographic ILO classification

- Currently the accepted means of quantifying dust exposure and dust retention
- Standardized technique
- Reader training necessary
- Important in evaluating disability claims
- Profusion of opacities first categorized as 1, 2, or 3
- Second sub-classification to indicate degree of certainty (0/0, 0/1; 1/0, 1/1,1/2 etc )
- Size and shape then classified
  - Rounded/regular; p <1.5 mm , q 1.5-3 mm, or r >3 to 10 mm
  - (N.B more specific for dust exposure)
  - Irregular opacities; s, t, or u based on the same sizes
  - Larger opacities are classified as A (1-5 cm), B (>5 cm), or C
    - (equivalent to the entire RUL zone)
  - Progression of disease is usually associated with a change in profusion, not size of opacities
- Presence/degree of pleural thickening recently reclassified
International Labour Organisation (ILO) Guidelines for classification of pneumoconiosis 2011

- Set of standard radiographs/digital images
- Correlates with histological features of CWP and with dust levels
- Useful epidemiologically
- Also classifies shape of lesions: rounded or irregular opacities
- Simple (uncomplicated CWP) = no evidence of large masses; increasing gradation of abnormality
- Complicated pneumoconiosis = large masses usually in upper lobes
- System takes into account the differences in interpretation between radiologists which are inevitable
- CT not included in ILO guidelines
First stage of CWP (1/1) and simple CWP

With higher dust levels:

- Formation of dust nodules (> 1 mm diameter).
- Nodules are required for the diagnosis of CWP and are generally radiologically visible
- Nodules palpable
- Emphysema usually more marked
- ? Associated with symptoms
Stage 2/3 CWP

- Increasing profusion of opacities
- Increasingly associated with symptoms
- Emphysema more prominent on lung sections
- Removal from dust exposure recommended
Complicated CWP

- Associated with severe respiratory symptoms
- Melanoptysis
- Right heart failure
- Death

- Easily mistaken for lung cancer especially in smoker but risk low
- No increased risk of silicosis in pure CWP
Different combinations of dust:

Mixed dust fibrosis

Simple dust nodule

Mixed coal and silicotic nodule
Silicosis

- Dusts in coal mining vary according to local mineral deposits
- Silica exposure common especially in cutting down to the coal seam and in bolting
- Silica produces different radiology, pathology and symptomatology
- PMF not specific for CWP and may occur in silicosis & other pneumoconioses
- Pleural involvement relatively common (rare in CWP except over areas of PMF)
- Increased incidence of lung cancer
Silicosis: nomenclature - as with CWP

Chronic:
- Simple silicosis
  - Small dense nodules throughout lungs but primarily in mid and upper lobes
  - Whorled nodules (onion-skin)
  - Pleural thickening common
  - Lymphadenopathy usual with frequent calcification
- Complicated silicosis
- Accelerated silicosis

Acute
- alveolar lipoproteinosis

Mixed dust fibrosis

Partial polarization of a silicotic nodule with faintly birefringent silica particles
Simple silicosis
Complicated silicosis

• Silicosis with the presence of large pneumoconiotic nodules i.e., progressive massive fibrosis (PMF) irrespective of clinical status

• Radiological not clinical definition

• PMF = ≥ 1 cm
Complicated silicosis
Complicated silicosis in 2016!
Dust-related diffuse fibrosis (DDF)

- Described in coal miners for >40 years, initially post-mortem series in USA and UK
- Associated with a restrictive rather than obstructive pattern on lung function
- Lower zone interstitial fibrosis with honeycombing
- Radiological and clinical picture almost identical to idiopathic pulmonary fibrosis
- Also occurs with other dusts (e.g. silica)
- Prevalence of DDF between 15-20% of autopsies (only 5-10% in normal population)
- Estimated that approximately 10-15% of patients attending IPF clinics have unrecognized occupational/environmental exposures
- May occur in the presence of emphysema (? Worse prognosis)
Lung cancer

• Coal miners exposed to carcinogenic substances: quartz, radon, diesel exhaust

• Despite this, initially believed that coal mining protective for lung cancer

• Interestingly, no increase in TB

• More recent studies ? Excess mortality and further studies are needed
COPD in coal miners

Reminder of definitions:

- Chronic bronchitis
  - Chronic productive cough for more than 3 months of the year for two successive years
- Emphysema
  - A chronic, irreversible disease of the lungs characterized by abnormal enlargement of airspaces within the lungs and accompanied by destruction of the tissue lining the walls of the airspaces
Global Initiative for Chronic Lung disease

GOLD definition

COPD is a common preventable and treatable disease characterized by persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways and the lungs to noxious particles or gases. Exacerbations and co-morbidities contribute to the overall severity in individual patients.

www.goldcopd.org
Risk Factors for COPD

- Cigarette smoke
- Occupational dust and chemicals
- Environmental tobacco smoke (ETS)
- Indoor and outdoor air pollution

Genes
Infections
Socio-economic status
Aging Populations

Global Strategy for Diagnosis, Management and Prevention of COPD
© 2015 Global Initiative for Chronic Obstructive Lung Disease
COPD/Chronic bronchitis & emphysema in coal miners: summary from a large literature

<table>
<thead>
<tr>
<th>Emphysema</th>
<th>Chronic bronchitis</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Usually centri-acinar emphysema (identical to smoking-related emphysema, but dust also present)</td>
<td>• Symptoms of cough, sputum production, shortness of breath and wheeze all associated with cumulative exposure to coal dust</td>
</tr>
<tr>
<td>• Bullous and pan-acinar emphysema may also occur</td>
<td>• Prevalence of chronic bronchitis in coal miners in USA currently approx. 35%</td>
</tr>
<tr>
<td>• Related to cumulative coal dust mine exposure and lung dust content</td>
<td>• Equivalence of 1 year of work at coal face with one pack year of smoking</td>
</tr>
<tr>
<td>• Exposure to dust and dust content of lungs are both significant predictors of extent of emphysema even after accounting for cigarette smoking and age</td>
<td>• Smoking effects equivalent, not greater than those of coal dust; no synergistic effect</td>
</tr>
</tbody>
</table>
Two studies from New South Wales

Leigh et al. Quantified pathology of emphysema, pneumoconiosis, and chronic bronchitis in coal workers.

Series of 886 postmortems on coal mine workers 1946-82
Assessed:
- % emphysema (Heard method)
- bronchial gland wall ratio (Reid index)
- chest radiography within 10 yrs of death
- history of work at coal face
- smoking history
- FEV1 within 5 years of death

Results:
- Severity of emphysema related to years of work on coal face independently of age
- Severity of emphysema significantly related to chest radiographic pneumoconiosis
- Significant relationship between severity of emphysema and pneumoconiosis
- Gland-wall ratio correlated with age of death and severity of emphysema but not yrs of face work or pnc severity
- Smoking not correlated with severity of emphysema
- FEV1 predicted significantly negatively correlated with bronchitis, emphysema, and pnc.
- Severity of lung disease decreased slightly over the 33 yr period

Leigh et al. Quantitative relation between emphysema and lung mineral content in coalworkers.
Occup Environ Med 1994; 51: 400-407

- Assessed the relationship between quantified emphysema at postmortem and coal and silica content in 264 underground coalminers
- Extent of emphysema had strong positive relation with coal content of lungs, age and smoking
- In lifelong non-smokers, emphysema was particularly strongly related to coal content and age
- Not changed by adding lung silica content
- Emphysema score highly correlated with FEV1 as measured within 45 years of death
- Degree of lung fibrosis strongly associated with lung silica content
- Role of silica unclear
Does coal mine dust have an effect on lung function even in the absence of radiological pneumoconiosis?


- Case control study of 1286 miners vs randomly selected non-occupationally exposed local control males in Nottinghamshire, UK
- Spirometry obtained 1286 miners, 567 men
- Controls had participated in a study on diet and lung disease
- Multiple linear regression to estimate the mean independent effect of mining on spirometry after adjustment for age, height, and smoking history

Results:
- Significant mean effect of mining on FEV1 after adjustment of -155 mls and greater in younger men
- 4.7% of miners and 0.7% of controls had a deficit of >1L from predicted FEV1
- Marginally significant effect of both smoking and mining for the 1L deficit
- Found evidence of a strong healthy worker effect
Lung function decrement sufficient to affect mortality

- Cumulative exposure to coal dust a significant risk factor for the development of emphysema and has an additive effect to smoking.
- Increased coal dust exposure is associated with increased risk of death from chronic obstructive pulmonary disease (COPD).
- In newly employed coal miners, bronchitic symptoms are associated with a rapid decline in lung function within 2 years after starting work.
- In evaluating impairment, the chest radiograph is helpful as a marker of exposure, but the diffusing capacity is most correlated with dyspnoea. The emphysema computed tomography score has good association with expiratory flow limitation.

- Summary:
  Latest studies further support the association of emphysema and COPD with coal dust exposure. Increased cumulative exposure may also increase risk of death from these diseases.

*Tomas S, Linus H. COPD/Chronic bronchitis & emphysema in coal miners* 
*Current Opinion in Pulmonary Medicine: 2011 (17): 123-125*
Role of surveillance: can this be improved?

**Symptoms**
- Standardized questionnaires
- Many well validated respiratory disease questionnaires now available

**Imaging**
- CT scanning clearly shown to be superior to chest X rays but standardization of technique and interpretation not yet accepted & widely agreed
- Mobile CT scanners now available; low doses and computerized algorithms

**Lung function**
- Spirometry well validated but needs to be performed properly and longitudinal results are far superior to single measurements
- Measurement of DLCO the most sensitive measure of emphysema and again serial measurements preferable
- However, lung function is not specific and therefore the whole clinical picture needs to be considered
- Disruption/anxiety/cost of surveillance measures need also to be taken into account
Improvements in understanding lung disease

• More sophisticated lung function tests
• Much improved imaging techniques including high resolution CT scanning and PET/CT scanning
• Better understanding of basic pathophysiology and molecular mechanisms
• Distinct clinical subgroups now being recognized e.g. ACOS, combined IPF/emphysema, diffuse panbronchiolitis.
• Targeted treatments now available e.g. LAM, alpha-1 antitrypsin deficiency
• Non-invasive methods e.g. FeNO, exhaled VOC analysis
• Semi-invasive methods e.g. EBUS, bronchoscopic valve insertion for emphysema
Chest radiography compared with CT
Emphysema software
Better distinction between different lung diseases

e.g. DPB, lymphangioleiomyomatosis (LAM)
Lung function and more...

Body plethysmography, fractional exhaled nitric oxide, electronic nose
Surveillance

• Need to have a practical approach
• Current system insensitive for full spectrum of coal dust lung diseases
• ? Add in measurement of DLCO when assessing lung function
• Also ?HRCT scanning in those with abnormal CXRs or greater than projected trajectory of lung function decline
• Better knowledge needed about local conditions in Australia and correlation with actual personalized dust levels
Recommendations for control of coal workers’ pneumoconiosis (CWP)

Thoracic Society of Australia and New Zealand


• **Goal:** Eliminate CWP in Australia

• 1. Exposure limits and monitoring protocols
  • Standardise across Australia and harmonise to international recommendations

• 2. Screening
  • Develop and implement a national screening program for at-risk workers
  • Questionnaire, imaging, lung function testing

• 3. Medical workforce training

• 4. A centralised occupational lung disease register
Conclusions

- Coal dust inhalation results in a variety of different lung diseases which are gradually becoming characterized.
- Classical pneumoconiosis is only one of several coal dust mine related lung diseases (CMDLD).
- Dust content is important and will alter the characteristics of the disorder produced.
- Australia is not immune from this problem!
- Surveillance is secondary rather than primary prevention; dust control is key; current methods will not pick up all coal dust related disorders.
- COPD likely to become increasingly recognized and not all due to cigarette smoking.
- Resurgence of CWP disappointing given the huge improvements in the last century.
- Likely that greater understanding of mechanisms and pathology will allow more targeted treatment, as for other lung diseases.
- Collaboration within the global medical world should facilitate optimizing miners’ lung health.