Occupational lung disease
In the mining industry

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Objectives

• Review pathophysiology of various lung diseases
• Understand the relative occurrence/burden of these lung diseases in mining
• Improve identification and recognition of occupational lung diseases
• Understand that primary prevention plays a key role in managing these conditions
Importance of respirology issues in mining

- The lungs are prime route of exposure for many circumstances
- Mining involves a broad range of potential inhalation toxins
- Respiratory pathology is a likely consequence
- Work-relatedness of lung issues may not be recognized due to latency, varied etiologies, etc.
- Diseases may be forgotten due to emphasis on injury
Respirology basics

- Asthma
- COPD
- rhinitis
- Acute pneumonitis
- Inhalation exposures
- Irritant reactions
- Pleural plaques
- Fibrotic lung disease (interstitial lung disease, pneumoconiosis)
- Lung cancer
- Mesothelioma
- Infectious disease
Etiology of diseases in the workplace

• Deterministic: the higher the exposure, the worse the disease
  • direct effects from radiation
  • hearing loss
  • pneumonitis
• Stochastic: the higher the exposure, the higher the probability of disease
  • Lung cancer
• Predilective: demonstrates predilection +/- dose-dependency
  • Allergic conditions (asthma, dermatitis, rhinitis)
WORK-RELATED ASTHMA
What is asthma?

• Chronic lung disease affecting over 3 million Canadians
• Three hallmarks:
  • Reversible
  • Airway inflammation (swelling)
  • Airway constriction (tightening)
• Brought on and aggravated by certain triggers (family history, allergy, allergens, infections, smoking, etc.)
Epidemiology
Work-related asthma is not uncommon (10-15%) but often under-recognized
Asthma in mining

- McHugh et al. (2010) found that workers in mining had the highest prevalence of asthma compared to other occupations in the US.
Classification
Work-related asthma (WRA)

Occupational Asthma

Sensitizer-induced (allergic)

Work-exacerbated Asthma (WEA)

Irritant-induced (reactive airways dysfunction syndrome: RADS)
Work-related asthma (WRA)

Occupational Asthma

Sensitizer-induced (allergic)

Work-exacerbated Asthma (WEA)

Irritant-induced (reactive airways dysfunction syndrome: RADS)
Sensitizer-induced occupational asthma

- Represents the majority of occupational asthma (>90%)

- Clinical features:
  - fulfils the classic criteria for an allergic response:
    - asthma usually occurs in a minority of those exposed
    - asthma develops only after an initial symptom-free period of exposure
  - latency period of sensitization may be weeks to many years
  - Symptoms worsen at work or shortly after work
  - Symptoms improve when away from work (initially – if exposure continues, improvement away may not happen)
Sensitizers

• There are over 300 known sensitizers, with more every year
  • high molecular weight – generally proteins
    ▪ e.g. latex, flour, animal dander
    ▪ more likely to act as antigens through an IgE mechanism
  • low molecular weight – generally chemicals
    ▪ e.g. isocyanates, metals
    ▪ pathophysiology of mechanism is not well understood
• at particular risk are those with general risk factors for asthma:
  • Atopy, co-existing infections
Potential sensitizers in mining

- Isocyanate and phenol-based resins have been used for tunnelling support and have been associated with asthma (Bertrand et al, 2007)
- Paint and cement was reported to cause asthma in gold miners (Cowie et al, 1996)
- Exposure to Rhizopus nigricans, a fungal contaminant, in a coal mine (Gemboa et al, 1996)
Work-related asthma (WRA)

Occupational Asthma

Sensitizer-induced (allergic)

Work-exacerbated Asthma (WEA)

Irritant-induced (reactive airways dysfunction syndrome: RADS)
Irritant-induced occupational asthma

- Represents a small fraction of OA (approx. 6%)
- Onset typically occurs within 24 hours of exposure to a *large quantity of a respiratory irritant*. That is, unlike sensitizer-induced OA, there is typically no latency period.
- Most will recover after a toxic inhalation injury; some do not
- There is persistence of symptoms beyond 12 weeks, possibly lasting years
- **Pulmonary testing shows objective evidence of asthma**
- There is some evidence to suggest that *chronic*, low-level exposure to irritants (dusts, gases, mists, fumes, smoke) that are irritating to the respiratory tract may cause asthma (Balmes 2002)
IIA in mining

- Piirila et al (1996) report on 9 miners who were accidentally exposed to sulfur dioxide in a mine explosion.
- A number of these workers went on to develop a persisting airway hyperreactivity, consistent with a history of IIA.
Work-related asthma (WRA)

Occupational Asthma

Sensitizer-induced (allergic)

Irritant-induced (reactive airways dysfunction syndrome: RADS)

Work- exacerbated / aggravated Asthma (WEA)
CAUSES

Work-Exacerbated Asthma
(also called work-aggravated asthma)

Exposure to workplace irritants or exertion at work may aggravate pre-existing or concurrent asthma, particularly in patient who have moderate or severe asthma, or who are uncontrolled, because they are not receiving optimal treatment.

Work-exacerbated asthma represented approximately half of work-related asthma seen in a Canadian clinic studies (Tarlo, 2000).

People with pre-existing asthma are still susceptible to sensitizers in the workplace

THIS IS COMPENSABLE IN ONTARIO
WEA in mining

- Mining is one of the most common industries that causes worsening of underlying asthma (Henneberger et al, 2002)
Diagnosis: a multi-step process

1. DIAGNOSE ASTHMA
2. SUSPECT WORK-RELATEDNESS
3. DETERMINE WORK-RELATEDNESS
Spirometry 101

- Measure of airflow and volume of lungs
- Most commonly consider FEV1 and FVC
Management of WRA

The three main components of the management of WRA are:
1. Treat the asthma as per the usual guidelines
2. Address issues of workplace exposure
3. Initiate compensation claim, if applicable
Management of WRA

- OA (sensitizer-induced)
  - *Remove from exposure:*
    - Longer duration of exposure leads to increased risk of permanence and increased severity of disease
    - Workers can react to very small amounts of exposure

- Irritant induced asthma (RADS)
  - Remove from work until symptoms resolve
  - Return to work should be considered a trial – may react to exposures for long period (some cases up to 2 years)

- Work Exacerbated Asthma (WEA):
  - Control exposure - engineering efforts, modified work
  - Respirator is not a solution
Management of WRA

- Initiate a compensation claim
- Sentinel health event: consider that others may be similarly affected
- All workers need education and information about managing their asthma, recognition of triggers and what to do about them + + + support.
- Employers and workplace parties also need this information as well as support in determining how they will manage the worker and address exposure issues
Secondary prevention (early recognition)

Workplace – Occupational Health Program

- Medical Surveillance
  - Specific program to assess for health effects from specific exposures at pre-set intervals (e.g. annual, semi-annual)
    - e.g. isocyanates
    - Trend analysis – is there a group change? If yes, what is it due to?
- PFTs, symptom questionnaire
- Identification of a case of sensitizer-induced asthma should sound an alarm within the workplace – hygiene measures should be implemented to control exposure
COPD
COPD (chronic obstructive pulmonary disease)

- Also called emphysema, chronic bronchitis
- Similar to asthma but irreversible
- Often caused by *smoking*: occupational relationship is often ignored/unrecognized
- Compensated in smokers: attenuate compensation based on smoking
COPD and mining

- Cumulative dust exposure may cause COPD
- Sampatakakis et al (2013) found that mining dust was associated with greater risk of COPD
- Graber et al (2014) found elevated rates of COPD mortality in miners (HR = 1.84, 95% CI = 1.05-3.22)
- Mohner et al (2013) reported on declining lung function in miners
- Etc.
COPD and mining

- Oxman et al (1993) reviewed the epidemiology regarding occupational dust exposure and COPD
- They identified a number of studies reporting an association between dust exposure and obstructive lung impairment (COPD)
- 35 years of work at a dust level of 2 mg/m3 can lead to significant impairment in lung functioning
• WSIB threshold (40mg/m3-years) developed from British coal mining cohort (1988): corrected for smoking
• Higher risks had been reported in silica workers; this extrapolated table did not take into account Si effect of quartz mining

### TABLE 1. Percentage Abnormality Attributable to Dust Exposure in a Cigarette Smoker with FEV₁, 65 Percent Predicted

<table>
<thead>
<tr>
<th>Respirable Dust (mg/m³)</th>
<th>Exposure (Years)</th>
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<tbody>
<tr>
<td></td>
<td>10</td>
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<tr>
<td>2</td>
<td>10</td>
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<tr>
<td>3</td>
<td>14</td>
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<td>4</td>
<td>19</td>
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<td>5</td>
<td>23</td>
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<td>6</td>
<td>27</td>
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Original data from Marine et al.2
COPD and occupation

• Largely associated with “dust” levels: may occur in any industry but most common in foundries, mining, heavy industry, welding

• More recent cohort studies are implicating lower levels of dust (e.g. Santo Tomas, 2011)

• Synergy with smoking (Blanc et al, 2009):
  
dust + smoking  OR = 14.1 (95% CI = 9.33-21.2)
Clinical aspects of COPD

- Diagnosis depends largely on lung function testing
- Screening/early detection is of limited use
  - Once impairment is found, disease is usually well-established
- Management options:
  - Puffers
  - Oxygen
  - PREVENTION IS KEY!
INTERSTITIAL LUNG DISEASE
Interstitial lung disease

- Scarring of lungs (interstitium)
- Also called pneumoconiosis, pulmonary fibrosis, restrictive lung disease
- Classic work-related lung diseases: asbestosis, silicosis,
- Any adult presenting with ILD should be asked about occupational exposures
- Usually strong dose-response: higher the exposure, the more chance of disease
Common types

- Asbestosis
- Silicosis
- Hard metal disease
- Berylliosis
- Hypersensitivity pneumonitis
- Coal worker’s pneumoconiosis
- Siderosis
- Aluminum oxide fibrosis
- Talc pneumoconiosis
Clinical aspects of interstitial lung disease

- Can be difficult to clearly diagnose
  - Based on radiographic (CT, CXR) findings
  - Based on history of exposure
  - Occasionally biopsy/autopsy may help
- Screening is of limited value
  - Once impairment is found, it is likely established
- Management is limited; there is no cure
  - Oxygen, lung transplant
  - PREVENTION IS KEY!
Epidemiology of pneumoconiosis in mining

- Annual incidence of 25.7 per 100,000 in mining industry (Meyer et al, 2001) in the UK
- Silicosis mortality rate dropped from 0.74 per million in 2001 to 0.39 per million in 2010
- Diesel Exhaust in Miners Study (DEMS):
  - Significantly elevated risk of pneumoconiosis (RR=12.20, 95% CI = 6.82-20.12)
Silicosis

• Industries: mining, foundries, construction, masonry, mining
• Typically nodular disease, predominance of upper lobes
• Progressive disease with no real cure
• Associated with tuberculosis: TB is 2 to 30x more common in those with silicosis (Cowie, 1994)
• Silica has been associated with connective tissue disorders (scleroderma, lupus, RA)
• CXR: symmetric nodules, initially upper zones
Sarcoidosis

- Granulomatous disease often causing lung lesions, including fibrosis, as well as other organ involvement
- Unlike other ILD, onset maybe more rapid
- Cause is unknown:
  - ? Infectious
  - ? Autoimmune
  - ? beryllium
### Asbestos: Types

**Serpentine**
- (93% of commercial use)
- Chrysotile

**Amphibole**
- (7% of commercial use)
- Actinolite, Amosite, Anthophyllite, Crocidolite, Richterite, Tremolite
Asbestosis

- Thought to occur from all subtypes of asbestos: fairly ubiquitous material
- Industries: construction (industrial, commercial, residential), mining, heavy industry, trades, insulation
- Long latency (20 to 40 years)
- Diffuse interstitial fibrosis with:
  - Restrictive pattern of disease on pulmonary function testing (but can see mixed pattern)
  - Impaired gas exchange
  - Progressive exertional dyspnea
  - Not a necessary pre-cursor of lung cancer (Finkelstein, 2010)
Case (pleural plaques)

- Mr. B. (76 years old) is referred by the family MD for pleural plaques found incidentally on CXR
- He worked as a millwright from 1956 to 1994 and describes extensive asbestos exposure
- He has no respiratory complaints
- Pulmonary function is normal:
  - $\text{FEV}_1 = 101\% \text{ pred}$; $\text{FVC} = 102\% \text{ pred}$
Case (pleural plaques)

• He has questions:
  • Will he get cancer?
  • Does he need more tests?
  • Can he apply for compensation?
  • Should he be followed into the future?
Pleural plaques

- Marker of exposure
- *Not* asbestosis
- latency = 20-30 years
- prevalence = 3-14% or more
- usually incidental findings
- ? not associated with impairment
- does not prognosticate for mesothelioma

(Greillier, 2008)
Berylliosis (chronic beryllium disease)

- Industries: used for alloying:
  - aerospace, electronics, metalwork, welding, nuclear
  - Found in the mining and extraction industry (Deubner et al, 2001)
- 3-10% of workers sensitized; difficult to establish safe level
- **Granuloma formation that mimics sarcoidosis**
- BeLPT (Sens = 0.6 to 0.7; Spec = 0.99) (Middleton et al, 2010)
- Management requires removal from Be exposure
- Be may also cause acute pneumonitis in high doses
Ribeiro et al, 2011

- Searched for CBD amongst 121 sarcoidosis patients
- 17/121 (14%) had beryllium exposure (alloying, construction, mining, nuclear)
- None had positive BeLPT (although false negative rates = 31.7% (Stange, 2004)
- Conclusions: need for careful history taking in sarcoid; Be exposure was not uncommon

- Fireman et al, 2004 did a similar study in Israel and found 3 of 47 sarcoidosis patients had CBD
- Muller-Quernheim, 2006 found that 34 of 84 Be-exposed sarcoidosis patients likely had CBD based on BeLPT
Hard metal disease

- From tungsten-carbide/cobalt alloy: extremely strong
- Occupations: grinding, rolling, cutting/tunneling tools, aerospace
- May be related to cobalt mining (Kerfoot et al, 1975)
- Prevalence = 0.7 to 13% (Fontenot, 2008)
- No clear dose-response reported
- Pathology = ? giant cell interstitial pneumonitis, desquamative interstitial pneumonitis
Idiopathic pulmonary fibrosis

- ATS Statement on IPF (2011):
  - Diagnosis of IPF requires:
    - “Exclusion of other known causes of interstitial lung disease (ILD) (e.g. domestic and occupational environmental exposures...)
    - “presence of a UIP pattern on high-resolution computed tomography (HRCT) in patients not subjected to surgical lung biopsy”: similar to asbestosis, HP
    - “accuracy of the diagnosis of IPF increases with multidisciplinary discussion between pulmonologists, radiologists, and pathologists experienced in the diagnosis of ILD”
  - “the natural history is variable and unpredictable”: unable to diagnosis IPF on clinical grounds
Are cases of IPF actually misdiagnoses of occupational conditions?


<table>
<thead>
<tr>
<th>Exposure</th>
<th>OR</th>
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<tbody>
<tr>
<td>agriculture</td>
<td>1.65 (1.20, 2.26)</td>
</tr>
<tr>
<td>wood dust</td>
<td>1.94 (1.34, 2.81)</td>
</tr>
<tr>
<td>metal dust</td>
<td>2.44 (1.74, 3.40)</td>
</tr>
<tr>
<td>stone/sand</td>
<td>1.97 (1.09, 3.55)</td>
</tr>
</tbody>
</table>
Are cases of IPF actually misdiagnoses of occupational conditions?


<table>
<thead>
<tr>
<th>Exposure</th>
<th>OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>asbestos</td>
<td>1.1 (0.6, 1.9)</td>
</tr>
<tr>
<td>metal dust</td>
<td>2.0 (1.0, 4.0)</td>
</tr>
<tr>
<td>talc</td>
<td>2.8 (0.7, 11.2)</td>
</tr>
<tr>
<td>animal dust</td>
<td>4.7 (2.1, 10.4)</td>
</tr>
</tbody>
</table>
LUNG CANCER
Lung cancer

- Attributable fraction to work: 6-29%
- Only a fraction of these are being reported in Ontario: 250 to 1200 new cases per year; 152 submitted in 2003
Lung cancer and mining

The following are IARC Group 1 (carcinogenic to humans) carcinogens that may be found in mining:

- Asbestos
- Beryllium
- Cadmium
- Chromium
- Diesel exhaust
- Nickel
- Radon
- silica
Lung cancer and mining

• Diesel Exhaust in Miners Study (DEMS), 2012
  • 12 315 miners in US
  • Elevated risk of lung cancer (RR=1.26, 95% CI = 1.09-1.44) and esophageal cancer (RR=1.83, 95%CI = 1.16-2.75)

• Rage et al (2014)
  • Uranium workers: elevated lung and kidney cancer rates

• Edwards et al (2014)
  • Radon exposures related to lung cancer
Radon

- decay product of Uranium 238
- Naturally occurring
- Two of radon’s decay daughters (Po214 and Po218) emit alpha particles
- Alpha particles are carcinogenic, but limited penetrance
- Radon becomes attached to dust particles, then are inhaled; they cause local lung damage leading to carcinogenesis
Mesothelioma

- Almost all are work-related (95%)
- Minimal exposure seems to be able to cause disease: *even brief, intermittent exposure*
- Many claims are being missed (Pichora, 2009)
Clinical aspects of cancer

• Early diagnosis is paramount if there is to be possibility of cure
• All cancers are not the same: prognosis/diagnosis/treatment varies considerably depending on cancer type and location
• Screening for cancers is very difficult; there are few studies that have clearly established the usefulness of tests, such as CXR, CT, blood tests, etc.
• Management is generally limited; outcomes are poor
• PREVENTION IS KEY!
Prevention
Prevention of respiratory disease

- Primary prevention is clearly the goal for effective management of respiratory disease in the mining industry.
- By the time disease is found, management is relatively futile.
- Early detection (such as medical screening) is usually very limited, except in the case of asthma.
The Prevention Continuum diagram illustrates the progression from primary to tertiary prevention with corresponding interventions. It categorizes elements as follows:

**Agent**
- Chemical
- Odour

**Exposure**
- Annoyance

**Early Symptoms**
- Cough/tight chest

**Clinical Signs**
- ↓ lung function

**Disability**
- Asthma

**Primary Prevention**
- At the source
- Along the path
- At the worker

**Secondary Prevention**
- Medical surveillance
- Assessment of symptoms

**Tertiary Prevention**
- Managing disability
KEY POINTS:

- Mining work involves potential exposure to many lung toxins
- The entire spectrum of disease may be seen in this industry
  - Asthma, fibrosis, cancer, COPD
- Understand the different lung diseases that may be encountered
- Prevention is clearly the most important management strategy
References / Resources

**Recommended Reading:**
Diagnosis and Management of Work-related Asthma: ACCP Consensus
http://chestjournal.chestpubs.org/content/134/3_suppl/1S.full.html
An Official ATS Proceedings: Asthma in the Workplace
Bernstein IL, et al. Asthma in the workplace… 2006
Asthmagens? UK Health and Safety Executive. 2001
http://www.hse.gov.uk/asthma/asthmagens.pdf

**Recommended Clinics:**
Occupational Health Clinics for Ontario Workers
www.ohcow.on.ca  (905) 549-2552
St. Mikes Department of Occupational and Environmental Health
www.stmichaelshospital.com/programs/occupationalhealth
(416) 864-5074

**Other**  Ministry of Labour Health & Safety Contact Centre
www.labour.gov.on.ca  1-877-202-0008
Contact:
Dr. Mike Pysklywec
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With thanks to: