Atelectasis/collapse – Definition

- Reduced inflation of all or part of the lung
- Resorption of air distal to obstructed airway commonest mechanisms of collapse
- Collapse – linear or lobar or complete
- Focus – lobar atelectasis

Causes

- Foreign body
- Mass effect
- Tension
- Volume loss – FRC
- ETT + RMB

Atelectasis - Outline

- Definition/Causes/Outcome
- Diagnosis (options)
- Prevalence
- Prevention
- Management
- Future / suggestions
Potential Outcome - An experts perspective

Pulmonary Perspective

The Role of Ventilation-induced Surfactant Dysfunction and Atelectasis in Causing Acute Respiratory Distress Syndrome

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Surfactant depletion
- Supine
- Monotonous spont. or mech vent breaths
- Sedation
- Surface tension
- Atelectrauma
- Changes in surfactant and surface tension precede onset ARDS
- Restoration of surfactant with sighs, prone positioning

Diagnosis

+ Lobar collapse (CXR vs CT) standard descriptors based on lobe(s) affected e.g. silhouette signs
+ Limited diagnostic accuracy of portable AP CXR in ICU to detect lobar collapse/atelectasis – especially intubated and mechanically ventilated
+ Routine daily CXR’s are not standard practice – therefore potential for under diagnosis until it causes clinical impact e.g. delay in weaning, hypoxaemia.

CXR use in ICU - Lakhal et al ICM 2012

104 French ICUs – point prevalence study
2/3rds ICU’s use on-demand CXR’s ordering
Associated with no increase in un-scheduled CXR’s
Was of higher clinical value than routine daily CXR ordering
Study did not assess if the on-demand strategy missed or delayed some diagnoses
Question: Is atelectasis associated with clinical changes?
Diagnostic accuracy CXR
Kitazono et al 2009 AJR 194 407-412

- 200 hemi-thoraces in 100 ICU patients (117 effusions of varying sizes small-medium-large)
- 4 radiologists – varying experience
- CT scan within 24 hours of CXR – retrospective review
- Small and medium sized effusions either misdiagnosed as parenchymal opacities or not seen at all!
- Pulmonary opacities such as atelectasis/pneumonia were often missed.

OPTIONS ...Thoracic Ultrasound

CXR vs Ultrasound
Koeze et al 2012 Clin Ultrasound Journal 4:1
14 yo female asthmatic – intubated/ventilated

CXR
Complete opacification
Effusion? Collapse? Pneumonia

Ultrasound
Hyperechogenic areas
CT scan - pneumonia

CXR vs Ultrasound
Koeze et al 2012 Clin Ultrasound Journal 4:1
16 yo male heart failure VA ECMO

CXR
Complete opacification

US
Compressive atelectasis
L pleural effusion
US guide to MHI/VHI therapy response
Cavaliere et al Minerva Anestesiol 2011

Sample US views

Radiological Report:
Clinical Details: Hypoxic on ventilation, septic, previous CXR
7 fluid overloaded.
Question/s: exclude evolving consolidation
The left UV line seems to have been withdrawn somewhat and needs to
be inserted further into the SVC.
Overall appearances have worsened with confluent and extensive
consolidation now present in the right lung

Significant resp deterioration, problems with CVVHF with 4 filter changes
MI, stented, IABP, occluded stents awaiting cardiac surg.
7 Impella and/or Surgery
SIMV PCV rate 24 peep 9 TV 600 FiO2 1.0
ABG 0900hrs: pH 7.22 CO2 6.6 PaO2 6.4 P/F = 6.4
7 For HFOV

R ICD
Approx 2 L
Drained

Request thoracic US – estimated 2 litre simple effusion R
SIMV PCV rate 24 peep 14 PC 16 TV FiO2 0.65
ABG 1300 hrs pH 7.3 PaCO2 6.4 PaO2 26 P/F = 40
Physiotherapy supine flat 2 person assist cough suction/mod thick sputum
ABG 1400 hrs: pH 7.418 PaCO2 4.38 PaO2 30.64 P/F = 47 and PaCO2 decr 1.4
Prevalence

- Issues with definition of atelectasis (especially with inaccuracy of chest radiograph and the disappearance of routine daily chest radiographs) – hence true prevalence unclear
- More accurate diagnosis with CT scan not feasible or desirable, use of bedside Thoracic ultrasound an option.
- Suggestion of monitoring more broad term ventilator-associated complications defined by sustained increase in ventilator support (Klompas et al 2011) to encompass conditions such as VAP, pulmonary oedema, atelectasis, pneumothorax.

PLoS ONE 6(3): e18062

Management Options

- Nothing – allow spontaneous resolution unless it has clinical impact e.g. hypoxaemia, weaning delay, VAP
- Depend on cause of condition
  1. FRC/EELV
  2. Secretions

Quick Resume - VHI for recruitment ALI/ARDS

- CPAP alone 30-40 cmH2O often used - may cause haemodynamic compromise – not as effective as staircase
- HR/BP/CVP not sensitive measures of changes in CO/delivery
- LIDCO/PiCCO would be more useful to monitor potential detrimental effects of VHI on delivery
- May need higher PEEP post VHI procedures
- Also lower FiO2 during and post recruitment associated with better maintenance of recruitment (Hedenstierna)
Mechanical behaviour of lobar collapse

Solitary lobar collapse changed the PV curve by inducing a significant hysteresis and a right shift of lower inflexion point (LIP) on the inflation limb, but had minimal influence on the deflation limb.

After creation of the lobar collapse, LIP was found at the pressure at which the collapse started to expand.

PV curves of lungs with solitary lobar collapse are similar to those found in ALI/ARDS. Inspiratory LIP indicated start of recruitment, and expiratory curves did not indicate the pressure at which collapse occurred.

MHI/VHI for secretion clearance alone?

- MHI/VHI utilised for secretion clearance
- Options type of circuit used, pressure inflated to, with/without PEEP - presumed FiO2 generally 1.0
- Focus slow prolonged inspiration with/without insp hold followed by rapid unobstructed expiratory flow
- VHI = volume controlled (controlled rate and flow), pressure support (up to 30 minutes), time period variable - presumed FiO2 as per baseline settings
- VHI may achieve better improvements in compliance c/w MHI...hence there may be improvements in lung recruitment
- Option – staircase recruitment manoeuvre
MHI: Maxwell and Ellis
Anaesthesia 2007 62: 27-33

- Mean time 1.45 s
- Mean volume 1.23 L
- PIF 1.51 l.s⁻¹
- PEF 3.26 l.s⁻¹
- I:E 0.63
- 26/34 occasions achieved I:E ratio for secretion clearance

However what PEEP level achieved?
Could this MHI strategy be used to achieve lung recruitment or modify procedure – prolonged I time, and use of PEEP

MHI Systematic Review - 2012

Benefits and risks of manual hyperinflation in intubated and mechanically ventilated intensive care unit patients: a systematic review

- 19 articles
- MHI may in the short-term facilitate secretion clearance, improve compliance and oxygenation but nil changes in patient outcomes
- Can be associated with some clinically insignificant side-effects (CO/HR/CVP)

Clinicians may inadvertently be recruiting lung or creating atelectatic lung – dependent upon patient condition, MHI procedure, patient position/FiO2, PEEP/No PEEP

Paulus et al 2011 - MHI post cardiac surgery
Reduced incidence atelectasis/higher FRC

Significantly higher FRC up to day 3 postop but difference disappeared day 5.

+ MHI + SLY with collapsed lung upper most - Rx for acute lobar collapse
+ MHI/VHI - short term improvements in sputum clearance, Crs, lung infiltrates
+ Improvements in DYNAMIC Crs – unclear of due to improvements sec clearance/lung recruitment or both?
+ Patients will predominantly be in spont modes or triggering vent breaths hence difficult/impossible to measure STATIC Crs
Physiotherapy should be considered for the treatment of acute lobar atelectasis (level B).

Body positioning and techniques to increase inspiratory volume and enhance forced expiration (level B).

Manual hyperinflation and suctioning are the techniques indicated, with the patient positioned with the affected lung up (level B).

2nd Outcomes
Bronch, Mortality, Lobar collapse

<table>
<thead>
<tr>
<th>Variable</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>p value</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lobar collapse</td>
<td>24 (33.3)</td>
<td>23 (33.3)</td>
<td>0.86</td>
<td>22 (31.8)</td>
<td>27 (43.8)</td>
<td>0.04</td>
</tr>
<tr>
<td>Bronch</td>
<td>1 (2.8)</td>
<td>6 (8.3)</td>
<td>0.15</td>
<td>1 (5.9)</td>
<td>2 (5.8)</td>
<td>0.53</td>
</tr>
<tr>
<td>Mortality</td>
<td>23 (38.3)</td>
<td>23 (38.3)</td>
<td>0.12</td>
<td>22 (31.8)</td>
<td>22 (31.5)</td>
<td>0.95</td>
</tr>
</tbody>
</table>

- Phase 2 significantly lower rate lobar collapse – for physiotherapy group
- Phase 1 trend greater need for bronchoscopy in control group
- Phase 1 trend mortality rate physio group approx 50% of rate in control group
- Study underpowered

2nd Phase study ABI GCS < 9

MHI suction 4 x 24 h/day vs standard care

Part A Prevention VAP = 144 patients

Part B Treatment of VAP = 33 patients

Outcomes:
Primary: VAP, Ventilation, ICU, Hospital Time – No differences
Secondary: Lobar collapse, Bronch - therapeutic

Positioning
Gas exchange and mechanics

Lateral positioning of ventilated intensive care patients: A study of oxygenation, respiratory mechanics, hemodynamics, and adverse events

- 34 intubated ventilated patients
- Bilateral, unilateral or No CXR infiltrates
- Up to 2 hours in SLY then back to supine

CONCLUSIONS: In this heterogeneous population, lateral positioning had no beneficial effect on gas exchange. However, in ventilated patients who were hemodynamically stable, it was well tolerated and not associated with significant serious adverse events. (Heart Lung 2007;36:272-286)

Unfortunately did not evaluate impact of positioning alone on radiological resolution
Unilateral lung pathology or no CXR changes - significant reductions in dynamic compliance with sidelying!
- ? Optimise PEEP with positioning to minimise FRC drop

Accuracy of chest radiographs to direct positioning strategies?
Alternatives...Ultrasound .. EIT ....and measure FRC during positioning

Summary/Recommendations

- Improve diagnosis of lobar atelectasis at bedside – Thoracic US – No radiation, repeatable measure to report on evolution of condition – with or without intervention
- Identify clinical significance of acute lobar atelectasis (quantify extent of atelectasis with clinical status of patient e.g. Fio2, PEEP, immobility, other medical device requirements) and determine if impacts on patient outcome (ventilation time, trache, VAP).
- Identify cause of atelectasis – secretion retention, FRC or volume loss – to determine optimal management
  1. Positioning - mobilisation
  2. MHVHI
  3. Secretion clearance or
  4. Natural resolution.