“Ventilatory Management of the Morbidly Obese Patient”
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- Obesity: excess of weight compared to the height of a person.
- Measured through Body Mass Index: BMI = (weight)/(height)^2 = kg/m^2
  - Normal: 20-25
  - Obese: 30-39
  - Severe obesity: 40-44
  - Morbid obesity: 45-49
  - Super obesity: 50-59
  - Super-super obesity: 60-69
  - Hyperobesity: >70

Ogden CL, et al. JAMA 2014
- Up to 36% of the US population obese
- Obesity associated with higher morbidity only for BMI > 35
- Up to 6.3% has a BMI > 40 kg/m^2

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Robert M Kacmarek
I disclose the following financial relationships with commercial entities that produce healthcare-related products or services relevant to the content I am presenting:

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El-Solh Chest
2001;120(6)
- Retrospective analysis of 117 MICU patients with BMI > 40
- 134 non-obese (BMI < 30) patients were randomly selected as comparison
Obesity
1) Obesity **by itself** not seem as a risk factor for mortality
2) Predictors of mortality in MV obese patients are associated with comorbidities respiratory, renal, cardiovascular
3) Obese pts require tracheostomies > non-obese for MV (poor oxygenation, difficult weaning)
4) Obese pts have a higher likelihood to develop ventilator-dependency
5) Ventilator dependency is the determinant of higher mortality after tracheostomy

**Physiological alterations associated with obesity**
- Respiratory
- Renal
- Cardiovascular (hypertension, obese cardiopathy)
- Endocrine (hypersecretion of renin)
- Metabolic (diabetes, hyperlipidemia)
- Inflammatory (pro-inflammatory cytokines from adipose tissue)
- Neurological (OSA, Obesity hypoventilation syndrome)

**Obese Non-Respiratory Pathophysiology**
- Proinflammatory cytokines
- Excess adipose tissue
- Increase in circulating blood volume
- Endocrine signaling for water retention
- Proinflammatory cytokines
- Chronic inflammation
- Inflammation
- Insulin resistance
- Reduced metabolic reserves
- Increased metabolic work (basal and activity)
- Increase in cardiac preload and output (dilatation)
- Increase in kidney filtration rate (increased CO)
- Increase in kidney hypertension
- Higher oxygen consumption, diminished physiological reserves, fragile equilibrium
- Reduced FRC
- Pulmonary shunting
- Dynamic hyperinflation
- Expiratory flow limitation
- Atelectasis
- Increased WOB

Respiratory alterations in obese

Reduction in lung volumes


Tidal breathing into Closed Capacity


Tidal breathing into Closing Capacity

=> Collapse of distal airways due to insufficient end-expiratory elastic traction, collapse of alveoli due to reabsorption of gases


Ventilation/perfusion mismatch

- Increase in dead space (VT reduced due to loss of West 3, increase of Vd/Vt)
- Increase in shunt
- Increase in pulmonary vascular resistance (increased right heart afterload)
- Less effective hypoxic vasoconstriction (higher CO)


Hypoxemia, lower VT, higher RR (to maintain VE), increased cardiac work

Effects of BMI on Airways

Table 1 — General Characteristics of the Subjects Included in the Study

<table>
<thead>
<tr>
<th>Group</th>
<th>BMI, kg/m²</th>
<th>BW, kg</th>
<th>Height, cm</th>
<th>Age</th>
<th>p-value</th>
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<tbody>
<tr>
<td>1</td>
<td>27 ± 2</td>
<td>77 ± 3</td>
<td>167 ± 2</td>
<td>38 ± 3</td>
<td>0.001</td>
</tr>
<tr>
<td>2</td>
<td>34 ± 1</td>
<td>103 ± 2</td>
<td>166 ± 1</td>
<td>38 ± 3</td>
<td>0.001</td>
</tr>
<tr>
<td>3</td>
<td>46 ± 2</td>
<td>120 ± 0</td>
<td>167 ± 2</td>
<td>45 ± 3</td>
<td>NS</td>
</tr>
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ANOVA: p<0.0001

BMI = body mass index, BW = body weight, values are expressed as means ± SEM.

Effects of BMI on Airways

Decrease in lung volume; inspiratory reserve volume and inspiratory capacity
Effects of BMI on Airways

- Increase in resistances correlated with BMI

Effects of BMI on Airways

- Increase in work of breathing

Obesity

- FRC reduction is exponential
- Increase in Raw dependent and proportional to FRC loss
- Higher prevalence of asthma-like symptoms
- Worsening of COPD symptoms

"WOB = WfgCrs + (Vt x Raw/t)"

Respiration in obesity – PEEP?

- Lower Cc, Cm
- Higher Raw
- V/Q Mismatch
- Body mass dependent
- Gravity dependent

The Role of PEEP

- Air trapping, atelectasis
- PEEP
- EFL reversal
- Prevention of atelectasis
- Mechanics and oxygenation improvement
- Is PEEP effective?

Effects of PEEP on the respiratory function of obese

Positive End-expiratory Pressure Improves Respiratory Function in Obese but not in Normal Subjects during Anesthesia and Paralysis

18 patients scheduled for abdominal surgery
- 9 morbidly obese
- Study protocol in the SICU after surgery
- 9 normweight as controls
- Study protocol in the OR

Effects of ZEEP and 10 cmH2O PEEP on respiratory mechanics and gas exchange

Respiratory

EELV at ZEEP:
2.15 ± 0.58 L vs 0.59 ± 0.18 L

EELV at 10 cmH2O PEEP:
2.76 ± 0.68 L vs 1.03 ± 0.29 L
Effects of PEEP and position on EFL in ICU obese patients

Excluded:
- Abdominal surgery, P/F < 200, asthma or COPD
- 15 with BMI > 35 kg/m²
- 15 with BMI < 30 kg/m²

VCV, constant flow, Vt 7-8 ml/kg IBW, RR 20

4 sets: ZEEP and autoPEEP-matched PEEP, during supine and sitting position

EFL assessment:
- Manual compression of the abdomen to force expiratory flow, then the flow/volume curve was superimposed with a non-MCA induced flow-volume curve

End Expiratory Transpulmonary Pressure!
- Normal Spontaneous breathing about 0-1 cmH₂O end expiratory transpulmonary pressure maintains alveoli open
- A negative end expiratory TPP results in alveolar collapse at end exhalation

TPP = PEEP - Ppl
1 cmH₂O = 0 cmH₂O – (-1 cmH₂O)

End Expiratory Transpulmonary Pressure
- End expiratory esophageal pressure used to determine the correct setting of PEEP

TPP = PEEP - Ppl
- 8 cmH₂O = 0 cmH₂O – (8 cmH₂O)
TPP = PEEP - Ppl
2 cmH₂O = 10 cmH₂O – (8 cmH₂O)
PEEP titration transpulmonary pressure

PEEP level is set to achieve a non-collapsing pressure at end-expiration (lowest PEEP value with positive end-exp transpulmonary pressure)

Inadequate PEEP

Adequate PEEP

Talmor NEJM 2008;359:2095

- Requires placement of esophageal catheter
- Difficult to position and maintain position
- Needs more study
- Arbitrary in its scaling
- Designed for use in ARDS patients

Performance of RM - PCV

- Pressure control ventilation, $F_{O_2}$ 1.0:
  - PEEP 25-35 cmH₂O
  - Pressure control level 15 cmH₂O
  - Inspir Time: 1 to 2 sec
  - Rate: Appropriate for patient
  - Time 2 min
- Initial RM PEEP 25 cmH₂O, PIP 40 cmH₂O
- Set PEEP at 25, ventilate VC, $V_{et}$ 4 to 6 ml/kg PBW, increase rate, avoid auto-PEEP
- Measure dynamic compliance
- Decrease PEEP 2 cm H₂O

Performance of RM - PCV

- Measure dynamic compliance
- Repeat until max compliance determined
- Optimal PEEP max comp PEEP+2 cm H₂O
- Repeat recruitment maneuver and set PEEP at the identified settings, adjust ventilation
- After PEEP and ventilation set and stabilized, decrease $F_{O_2}$ until PO₂ in target range
- If response is poor, repeat RM, PEEP 30, Peak Pressure 45
- If response is poor, repeat RM, PEEP 35, Peak Pressure 50

Suarez-Sipmann CCM 2007;35:214

Suarez-Sipmann CCM 2007;35:214
PEEP in Morbid Obesity
- Chest wall Elastance not elevated and not affected by PEEP
- Respiratory System and Lung elastance increased by appropriate PEEP levels following RM
- PEEP following RM is titrated for optimal stabilization of lung volume
- Average PEEP following RM 20 cmH2O
- RM and PEEP well tolerated hemodynamically
- Head of Bed >30 improves lung mechanics

End Inspiratory Transpulmonary Pressure!
- Normal Spontaneous breathing about -2 to -4 cmH2O end inspiratory transpulmonary pressure
  \[ TPP = P_{plat} - P_{pl} \]
  \[ -3 \text{ cmH}_2\text{O} = 0 \text{ cmH}_2\text{O} - (3 \text{ cmH}_2\text{O}) \]

End Inspiratory Transpulmonary Pressure
- End inspiratory esophageal pressure used to determine the limits of inspiration
  \[ TPP = P_{plat} - P_{pl} \]
  \[ 25 \text{ cmH}_2\text{O} = 28 \text{ cmH}_2\text{O} - (3 \text{ cmH}_2\text{O}) \]
  \[ 13 \text{ cmH}_2\text{O} = 28 \text{ cmH}_2\text{O} - (15 \text{ cmH}_2\text{O}) \]

Scaling of the Lung in Mammals
- Adapted from SM Tenney & JE Reamers, Nature 1963; 197:54-6; K Schmidt-Nielsen, 1972

Ventilation Morbidly Obese
- \( P_{PLAT} < 28 \text{ cmH}_2\text{O} \), unless increased chest wall compliance
- Lower the \( P_{PLAT} \), better the outcome
- RR limit based on autoPEEP, up to 40 or greater?
- \( P_{PLAT} \geq 28 \text{ cmH}_2\text{O} \), \( V_T \) 4-5 ml/kg
- \( P_{PLAT} \) 25 to 28 cmH2O, \( V_T \) 6 ml/kg
- \( P_{PLAT} \leq 25 \text{ cmH}_2\text{O} \), \( V_T \) 6-8; if patient has a strong ventilatory demand, better to allow a little larger \( V_T \) then to heavily sedate and force a very low \( V_T \)!

Thank You