

Intraoperative Mechanical Ventilation

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Disclosures

- ▶ Nothing to disclose
- ▶ (But I am an Intensivist)

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Learning Objectives

- ▶ Review post-operative pulmonary complications (PCC's)
- ▶ Summarize types of ventilator associated lung injury
- ▶ Discuss evidence for lung-protective ventilation (LPV) intra-operatively
- ▶ List strategies for lung-protective ventilation in special cases (obesity, cardiac surgery, one-lung ventilation)

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Background

- ▶ Standard of care had been high tidal volumes to reduce atelectasis
- ▶ Low PEEP to avoid hemodynamic effects

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Era of Low Tidal Volumes

- ▶ Extensive data in injured lungs/ARDS
- ▶ ARDSNET 2000-significant mortality benefit¹
 - ▶ TV 4-6 cc/kg IBW
 - ▶ PEEP to prevent atelectasis
 - ▶ Minimize driving pressure²
- ▶ But is this relevant in healthy lungs?
- ▶ Can we use lung-protective ventilation to prevent PPC's?

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Post-Op Pulmonary Complications

- ▶ Includes respiratory infection, respiratory failure, PTX, bronchospasm, aspiration, PE, ARDS
- ▶ Incidence 2-5%
- ▶ More common than post-op cardiac complications
- ▶ Second most common after surgical site infections
- ▶ Most common PPC is post-op respiratory failure

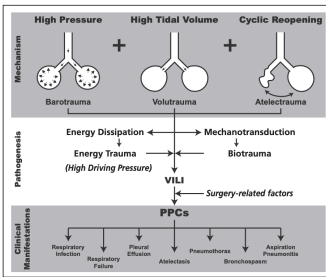
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Impact of PPC's

- ▶ 1 in 5 patients with PPC's die within 30 days of surgery vs <3% of those without PPC's
- ▶ 90 day mortality 22% vs 1%
- ▶ Length of stay increased by 13-17 days
- ▶ Increased hospital costs³

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Ventilator Induced Lung Injury (VILI)⁴



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Wolthuis et al-Biomarkers suggest VILI

- ▶ 2006 study
- ▶ 40 patients
- ▶ 12cc/kg IBW 0 PEEP vs 6cc/kg IBW 10 PEEP
- ▶ High TV low PEEP Associated with increased inflammatory biomarkers on BAL⁵

➔ Ventilation strategy of high tidal volumes and low PEEP may increase inflammatory biomarkers and therefore injury lungs

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Severgnini et al-LPV in Open Abd Surg (1)

- ▶ 2013 study
- ▶ Performed in Italy
- ▶ 56 patients, open abdominal surgery
- ▶ 9cc/kg IBW TV 0 PEEP vs 7cc/kg IBW TV 10 PEEP, RM's
- ▶ Primary outcome: clinical pulmonary infection score (temperature, WBC, pulmonary secretions, P/F, infiltrates on CXR)
- ▶ Excluded BMI>40

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Severgnini et al-LPV in Open Abd Surg (2)

- ▶ Lower modified clinical pulmonary infection score in protective ventilation group
- ▶ Protective ventilation group-better PFT's up to day 5, less CXR findings, better oxygenation, shorter LOS
- ▶ No association with increased intra-op complications or non-pulmonary organ failures
- ▶ No major hemodynamic consequences from high PEEP
- ▶ RM's not associated with life-threatening reductions in SBP/HR

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Severgnini et al-LPV in Open Abd Surg (3)

The bar chart displays the modified Clinical Pulmonary Infection Score (mCPIs) for two ventilation strategies: Standard Ventilation (red bars) and Protective Ventilation (blue bars) at three time points: Day 0, Day 1, and Day 3. The y-axis represents mCPIs from 0 to 4. Error bars are shown for each bar. Asterisks (+) indicate statistical significance for the Standard Ventilation group at Day 1 and Day 3, and for the Protective Ventilation group at Day 3.

Day	Standard Ventilation (mCPIs)	Protective Ventilation (mCPIs)
Day 0	~0.2	~0.3
Day 1	~1.5*	~0.8*
Day 3	~1.9*	~0.7*

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Severgnini et al-LPV in Open Abd Surg (4)

➔ Small RCT in intra-abdominal surgery patients shows association between protective ventilation using low TV and high PEEP and reduced PPC's⁶

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Futier et al-RCT LPV in Abd Surgery (1)

- ▶ 2013 study in France
- ▶ 400 patients intermediate to high risk for PPC's
- ▶ Major abdominal surgery
- ▶ Excluded BMI>35
- ▶ Lung protective strategy: 6-8cc/kg IBW TV, PEEP 6-8, RM's q30 mins
- ▶ Non-protective strategy: 10-12 cc/kg IBW TV, no PEEP, no RM's

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Futier et al-RCT LPV in Abd Surgery (2)

- Primary outcome:
- Composite of major pulmonary (PNA, invasive or non-invasive ventilation for acute respiratory failure) and extra pulmonary (sepsis, death, abscess, anastomotic leak, unplanned re-exploration) complications within 7 days of surgery

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Futier et al-RCT LPV in Abd Surgery (3)

- ▶ Results: primary outcome occurred in 10.5% in lung-protective group vs 27.5% non-protective group
- ▶ Requirement for noninvasive ventilation or intubation 5% vs 17%
- ▶ LOS 2.45 days shorter in protective ventilation group

➡ Larger RCT reinforces association between PPC's and non-protective intra-operative mechanical ventilation?

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Ladha et al-Large retrospective study LPV (1)

- ▶ 2015 study
- ▶ 3 centers in Boston
- ▶ Broadens scope of study-69,000 pts having general anesthesia with ETT, non-cardiac
- ▶ Considered to have received protective ventilation if PEEP>=5, median TV<10cc/kg IBW, median plateau pressure <30 cmH2O
- ▶ Primary outcome: Composite of major respiratory complications

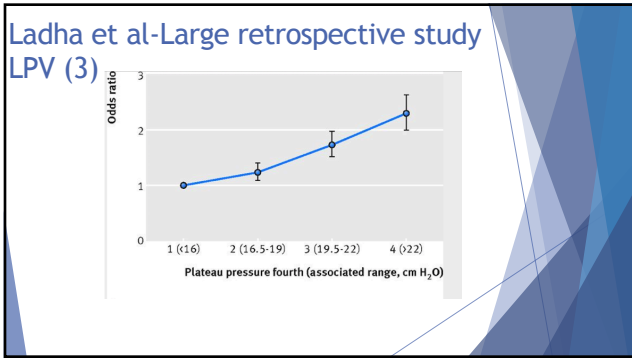
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Ladha et al-Large retrospective study LPV (2)

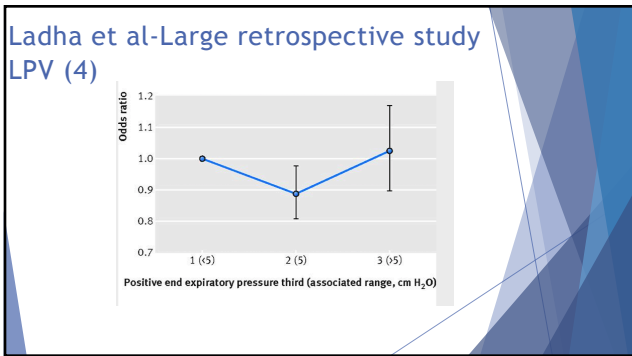
▶ Results:

- ▶ Median plateau pressure <16 protective
- ▶ Driving pressure >13 causes 2x increase in PPC's
- ▶ PEEP-5 or >5 associated with slightly higher OR for PPC's
- ▶ TV no significant impact

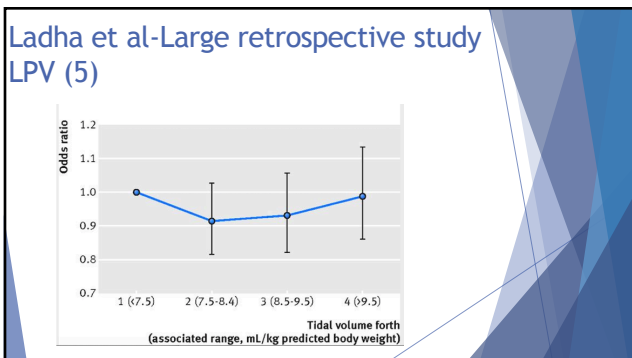
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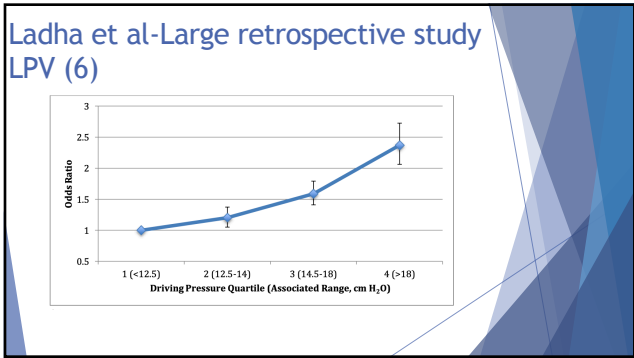
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- ### Ladha et al-Large retrospective study LPV (7)
- Large retrospective study identified plateau pressures >16 and driving pressure>13 as risk factors for PPC's
 - TV's not identified as a risk factor but chose higher TV's than prior RCT's⁸

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- ### Neto et al-Meta analysis LPV (1)
- ▶ 2015 study
 - ▶ 15 RCT's of 2127 patients
 - ▶ Major abdominal surgery
 - ▶ TV<8cc/kg IBW with or without PEEP vs TV>8cc/kg IBW
 - ▶ Primary outcome: Development of PPC's

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Neto et al-Meta analysis LPV (2)

- ▶ Results: rates of PPC's 8.7% LPV group vs 14.7% conventional
- ▶ Low TV high PEEP vs low PEEP no difference in PPC's

Systematic review and meta analysis finds dose dependent relationship between TV and PPC's⁹

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Cochrane Review-PEEP to prevent PCC's

- ▶ 2010 study
- ▶ Intra-op PEEP to prevent mortality and PPC's
- ▶ 8 RCT's, 330 pts
- ▶ No mortality benefit, higher P/F on POD1, less atelectasis, no increased barotrauma or cardiac complications in high PEEP

Cochrane review concludes no mortality benefit or reduction in PPC's with PEEP although PEEP seems to be safe¹⁰

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Hemmes et al-High vs low PEEP (1)

- ▶ 2014 study
- ▶ Multicenter RCT 900 patients open abd surgery
- ▶ TV 8cc/kg IBW, PEEP 12 vs 2 or less
- ▶ Primary outcome: Composite of PPC's by post-op day 5

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Hemmes et al-High vs low PEEP (2)

- ▶ Results: PPC's 40% high PEEP vs 39% low PEEP
- ▶ High PEEP group needed more vasoactive drugs, more intra-op hypotension

➡ RCT comparing high PEEP to low PEEP no difference in PPC's, more hemodynamic consequences¹¹

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What is the right FiO2?

- ▶ 2016 WHO guidelines advocate 80% FiO2 for prevention of SSI¹²
- ▶ 2017 retrospective review including 73,922 pts undergoing non CT surgery, 31% FiO2 vs 79% FiO2, median FiO2 associated with dose dependent increase in respiratory complications and 30 day mortality¹³
- ▶ 2019 systematic review meta analysis 17 RCT's 80% FiO2 no reduction of SSI¹⁴
- ▶ 2019 systematic review meta analysis 17 RCT's 80% FiO2 no increased AE's¹⁵

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FiO2 Controversy: Unresolved

- ➡
 - Retrospective data connect FiO2 80% with PPC's and mortality but meta-analysis of 17 RCT's shows no association
 - Limited data for prevention of SSI with FiO2 80%
- Coming soon-RCT comparing 30% FiO2 with 80% FiO2 in abdominal surgery, primary outcome incidence of PPC's¹⁶

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In Summary: Intra-op LPV

- ▶ Good evidence for TV 8cc/kg IBW to prevent PPC's
- ▶ Role of PEEP controversial-high PEEP not recommended, PEEP of 5 may be ideal based on retrospective data
- ▶ Recruitment maneuvers controversial
- ▶ Retrospective data suggests ideal plateau pressure <16, driving pressure <13
- ▶ FIO2 data murky, high FIO2 doesn't seem to prevent SSI, potential association with PPC's

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Special Cases

- ▶ Obesity
- ▶ Cardiopulmonary Bypass
- ▶ One-lung Ventilation

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Wang et al-Intra-op Ventilation in Obesity

- ▶ 2015 meta-analysis, 13 RCT's, 476 patients
- ▶ High heterogeneity
- ▶ VCV PEEP>10 single RM associated with highest P/F, highest intra-op pulmonary compliance, prevention of intra-op atelectasis

➡ Meta-analysis suggests high PEEP with a single RM is effective in obese patients, due to high heterogeneity no conclusions about TV can be drawn¹⁷

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Zupancich et al-LPV in CBP Biomarkers

- ▶ 2005 study in Italy
- ▶ 40 pts, elective CABG, TV 10-12 cc/kg IBW 2-3 PEEP vs TV 8cc/kg IBW, PEEP 10
- ▶ Measured IL6,8 in BAL in plasma, significantly higher after 6h mechanical ventilation post CBP without LPV

➔ Small study associates inflammatory biomarkers with high TV's after just 6 hours of mechanical ventilation in the post CBP population¹⁸

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Sundar et al-RCT of LPV in CBP

- ▶ 2011 study
- ▶ 149 pts, elective cardiac surgery, stopped ventilation during CBP, RM at conclusion
- ▶ 6cc/kg IBW TV vs 10 cc/kg IBW
- ▶ Primary outcome: Time to extubation-no change, low TV group less post-op re-intubation

➔ No change in time to extubation but suggestion of benefit to low TV based on less post-op re-intubation¹⁹

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Lui et al-Meta Analysis of OLV

- ▶ 2016 study
- ▶ Meta analysis, 11 RCT's, 436 pts
- ▶ TV<6cc/kg IBW vs TV>7cc/kg IBW
- ▶ LPV decreased incidence of PPC's (OR 0.29), no effect on MAP or LOS, no difference in VCV vs PCV

➔ Systematic review and meta analysis finds decreased PPC's in patients undergoing one lung ventilation with low TV²⁰

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In Summary: Special Cases

- ▶ Obesity-High PEEP and single RM may be beneficial, more data needed
- ▶ Cardiopulmonary Bypass-Low TV's may decrease re-intubation, more data needed
- ▶ One-lung Ventilation-TV-6cc/kg IBW decreases incidence of PPC's

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Thank you!

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