Management of one lung ventilation during thoracic surgery – Impact on postoperative complications

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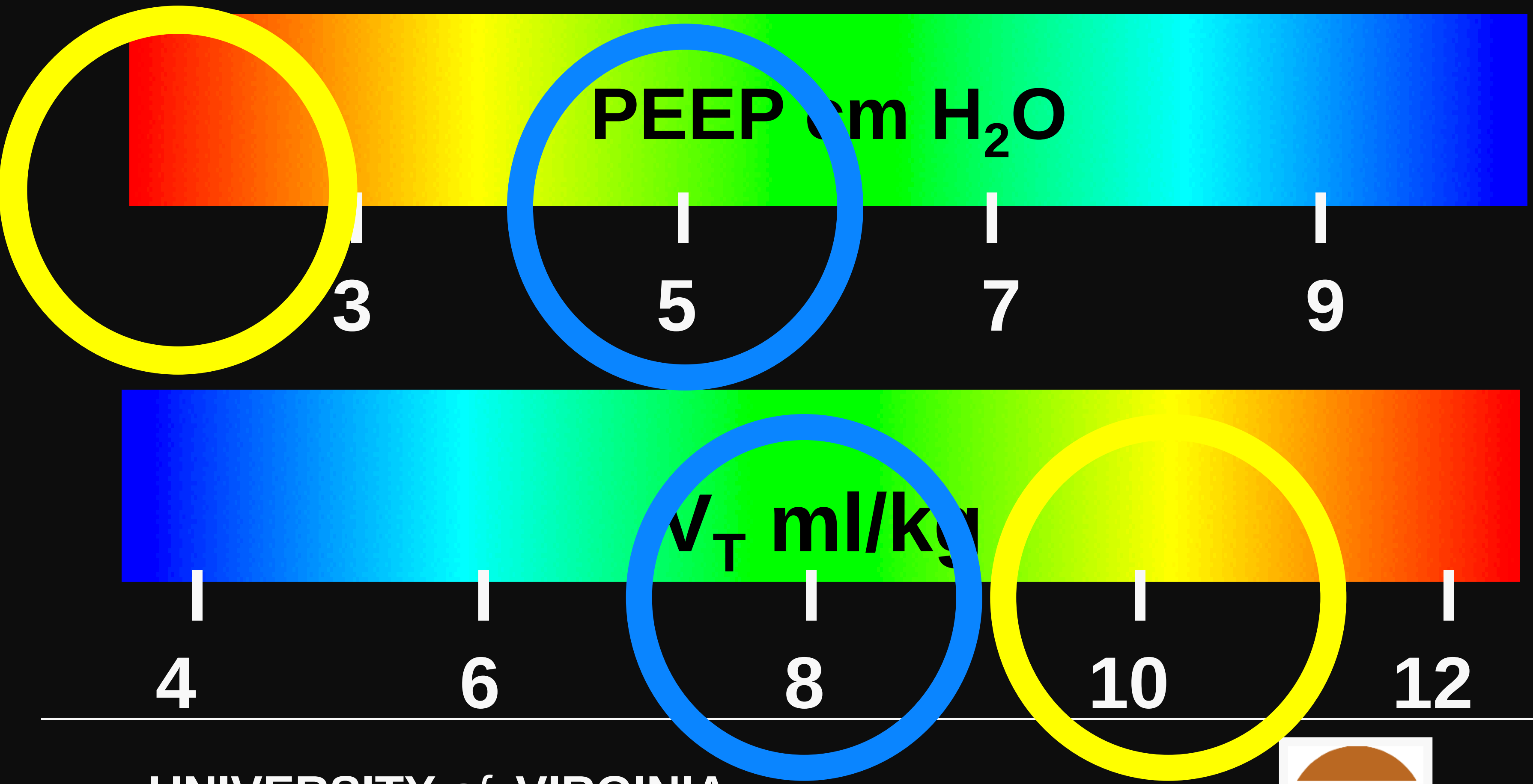
Lung Protective Ventilation

- Potential for outcome improvement
- RCTs
  - Bundled ventilator variables (V_T, PEEP)
  - Control groups not reflecting standard practice
  - Large composite primary outcomes
- Incompletely defined
- No clinical standard

LPV Bundles



What we don't know about LPV

- Exactly what LPV is!
- Ideal
  - V_T
  - Combination V_T, PEEP
- Whether PEEP 5 cm H_2O is sufficient
- Safe limits of airway pressure (ΔP)
- Contribution of practice Δ to outcome Δ

Overall Aim

- Assess relationship
  - management of 1LV
    - V_T, PEEP, P_{aw}
  - Postoperative complications

MPOG – STS Integration

Integration obstacles:

- Personnel
  - Thoracic surgery/CT anesthesia champions
  - STS & MPOG site IT champions
- Politics
  - Data security / privacy
  - Collaborative spirit between CT surgery/anesthesia
- Regulatory
  - MPOG participating site IRB → STS integration language

Outcomes

- Primary outcome - PPCs
  - Tracheostomy
  - Empyema requiring treatment
  - Pneumonia
  - Reintubation
  - Initial ventilator support > 48 h
  - ARDS
  - Bronchopleural fistula
  - Pulmonary embolism
  - Air leak > 5 d
  - Atelectasis requiring bronchoscopy
  - Respiratory failure
- Major morbidity
  - PPCs – any
  - Unexpected return to OR
  - Dysrhythmia requiring Rx
  - Myocardial infarction
  - Sepsis
  - Renal failure
  - Central neurologic event
  - Unexpected ICU admission
  - Anastomotic leak
- Composite
  - Any major morbidity
  - Mortality

Aim 1

- To determine whether adherence to putative LPV regimen predicts improvements in clinical outcomes?
  - LPV = $V_T \leq$ 5 ml/kg PBW and PEEP $\geq$ 5 cm H_2O
  - Non LPV = $V_T >$ 5 ml/kg PBW or PEEP $<$ 5 cm H_2O
- To determine whether the documented increase in adherence to LPV recommendations over the study period is associated with improved clinical outcomes

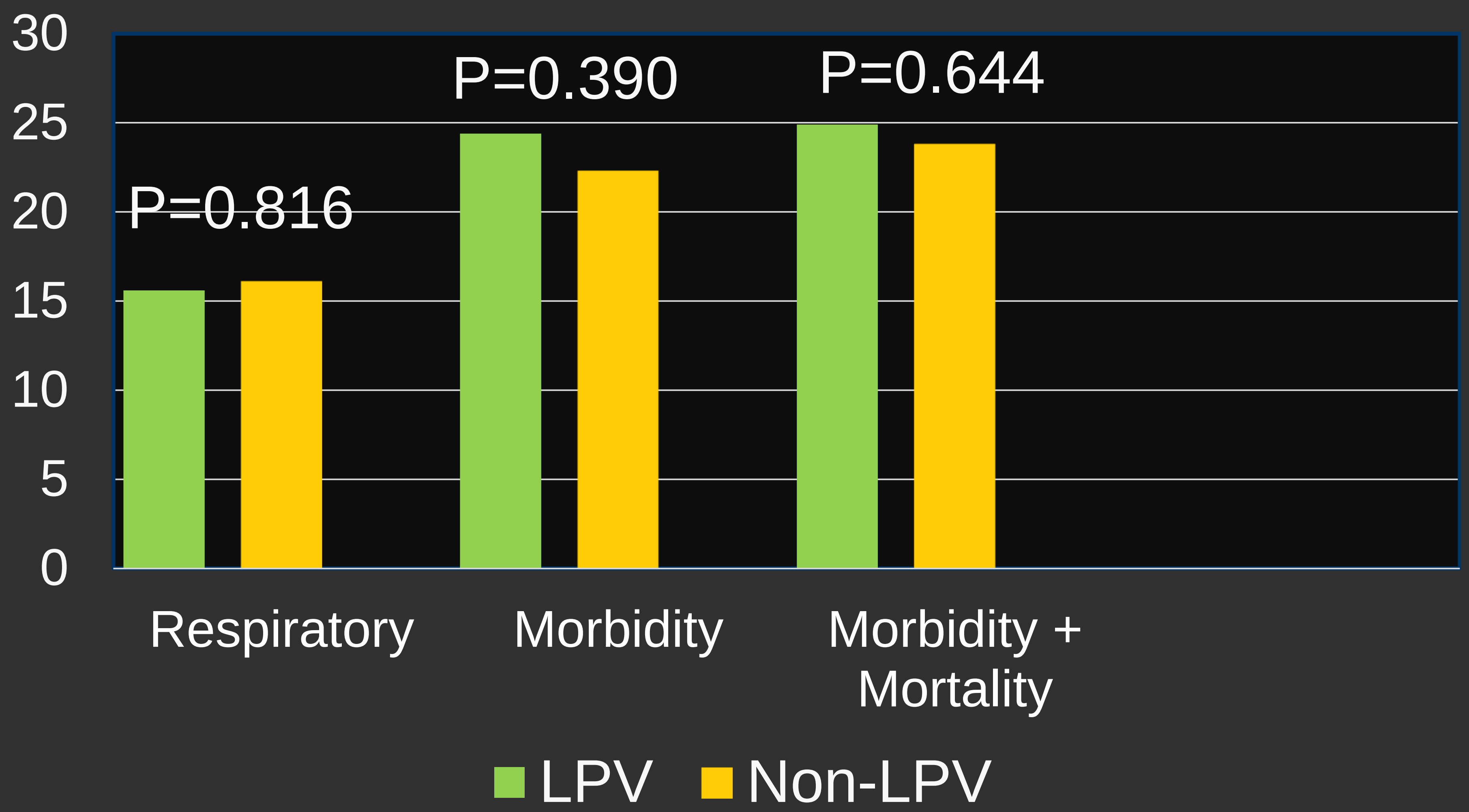
Unmatched

Demographics	No LPV N=3929	LPV N=621	P value
Age	63	63	0.203
Female sex	2084	192	<0.001
BMI	27.6	26.2	<0.001
ASA Class 3 or higher	74.6%	72%	0.166

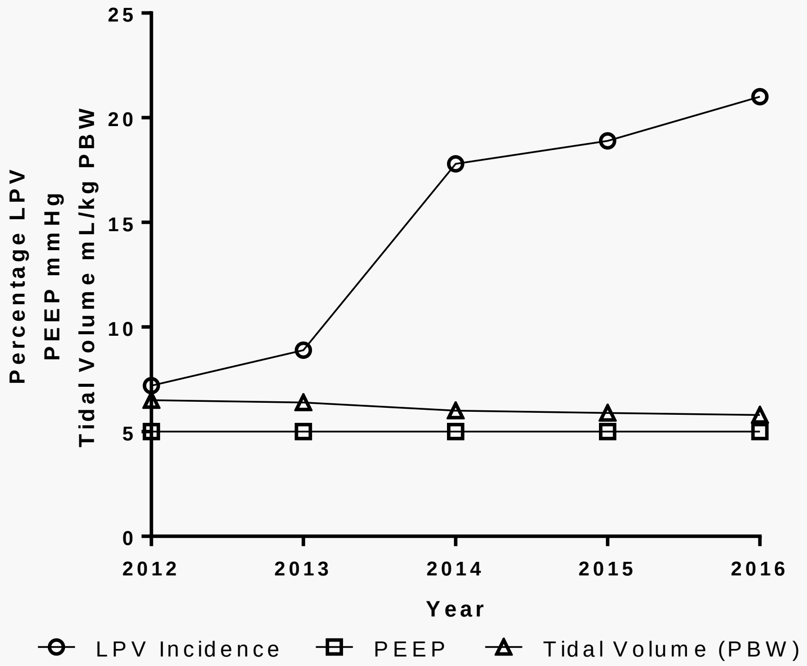
- Propensity score matched cohort (12 variables)
- LPV matched 1:1 with controls

Ventilation	Non LPV	LPV	P Value
Respiratory Rate	**12**	**14**	**<0.001**
FIO_2%	95	95	0.661
Mean P_{insp}	10	10	0.607
PIP	**22**	**21.5**	**0.001**
P_{PLAT}	20.5	20	0.387
$ETCO_2$	**34.1**	**38**	**<0.001**
V_T (ml/kg) PBW	**6.2 (5.6-7.0)**	**4.5 (4.1-4.8)**	**<0.001**
PEEP	**5 (4.0-5.0)**	**5 (5.0-5.0)**	**<0.001**
mΔP	**16 (13.0-20.0)**	**14 (11.0-18.0)**	**0.013**

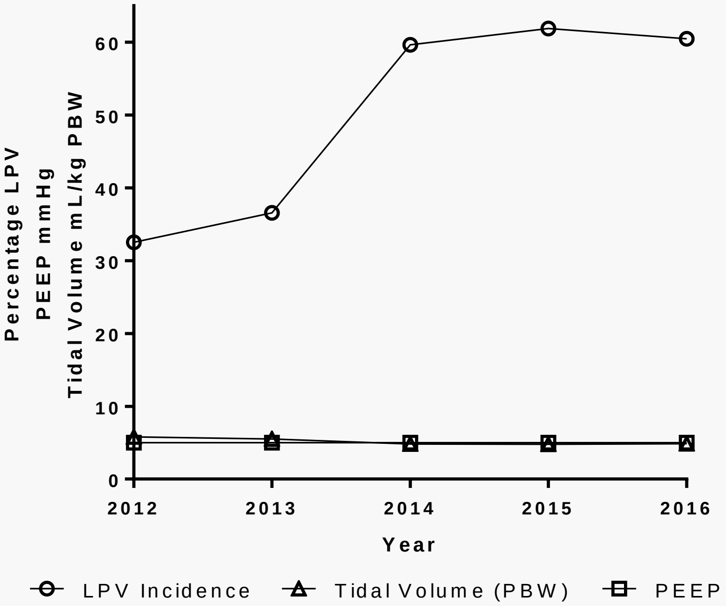
LPV and Outcomes



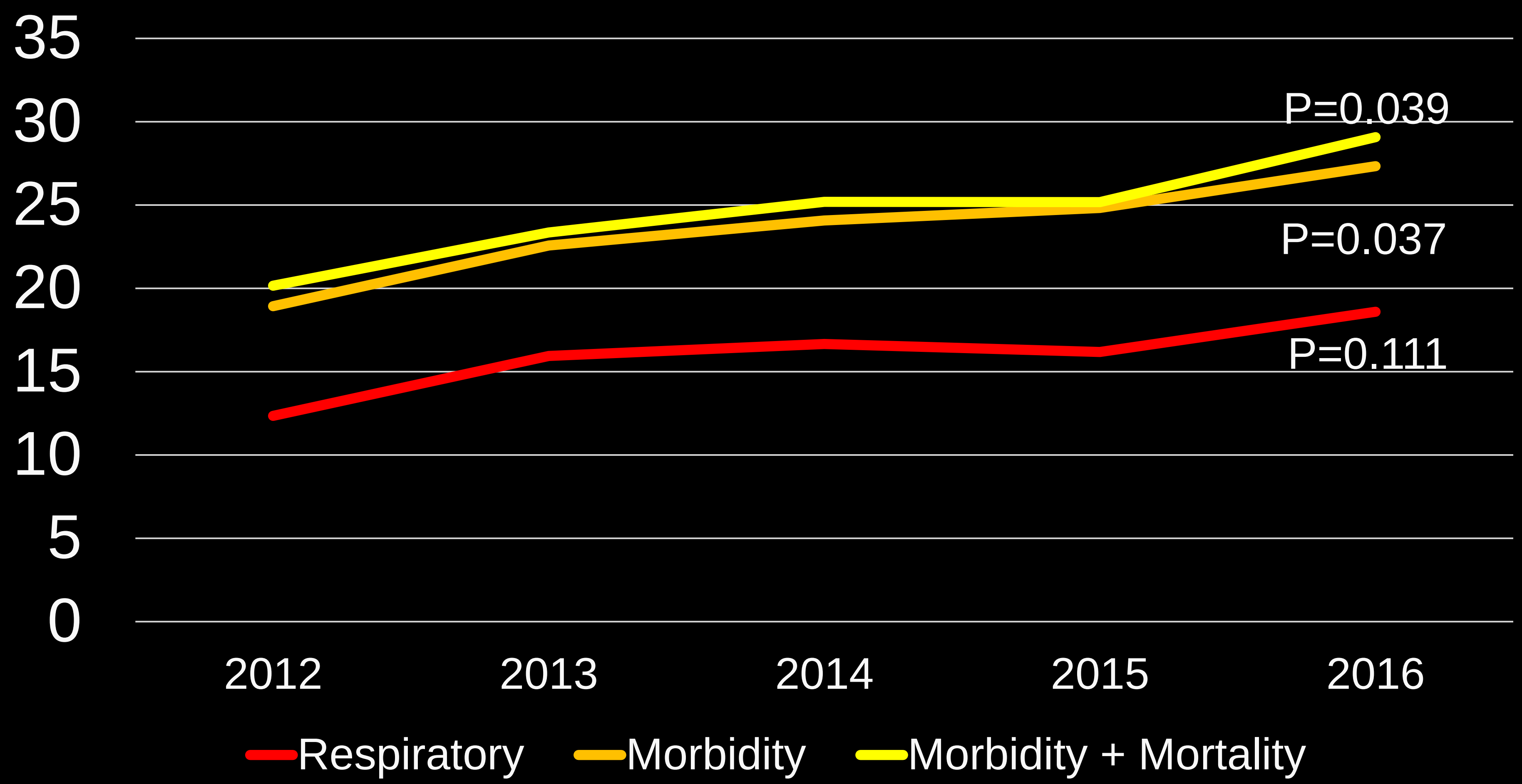
Unmatched



Matched

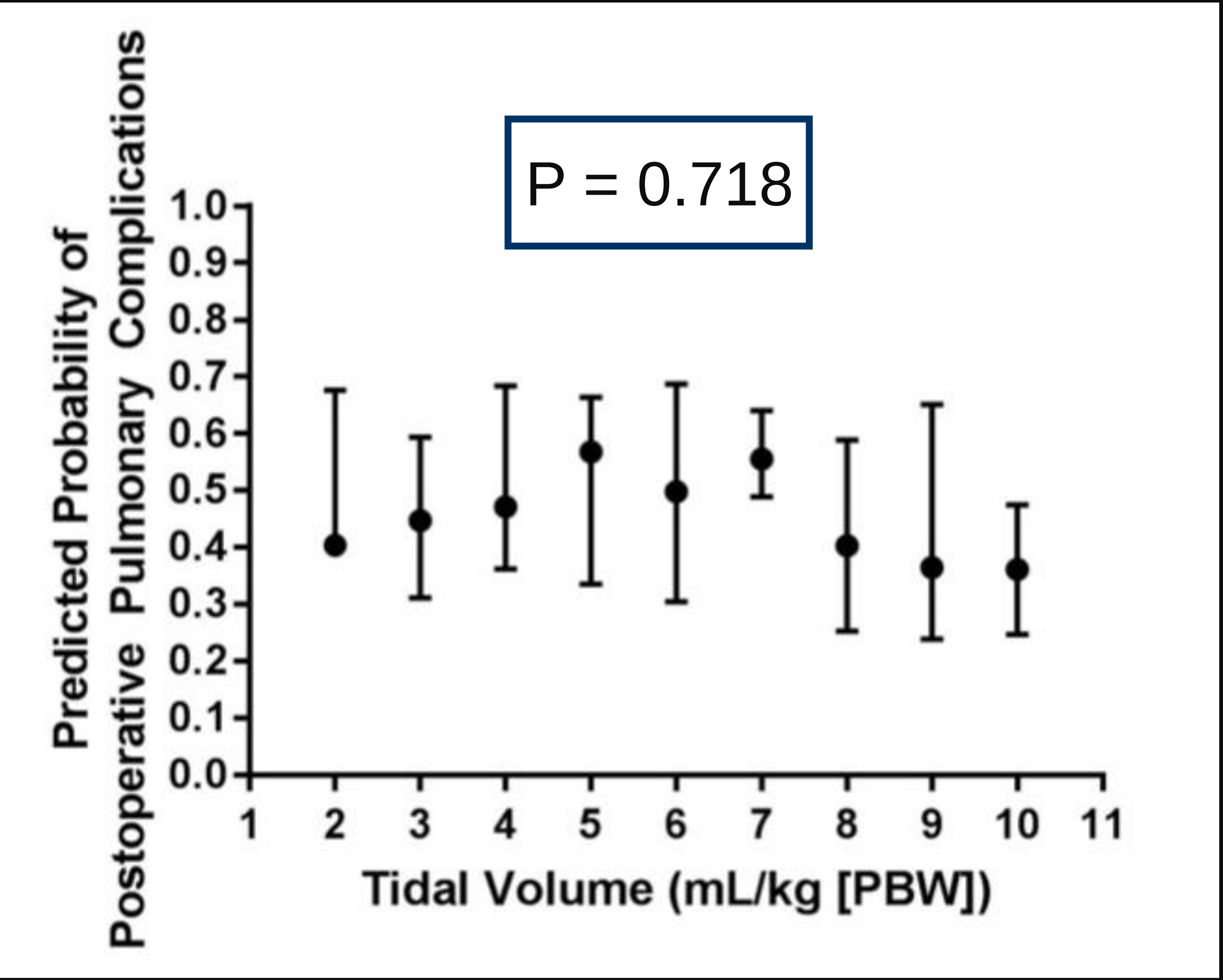


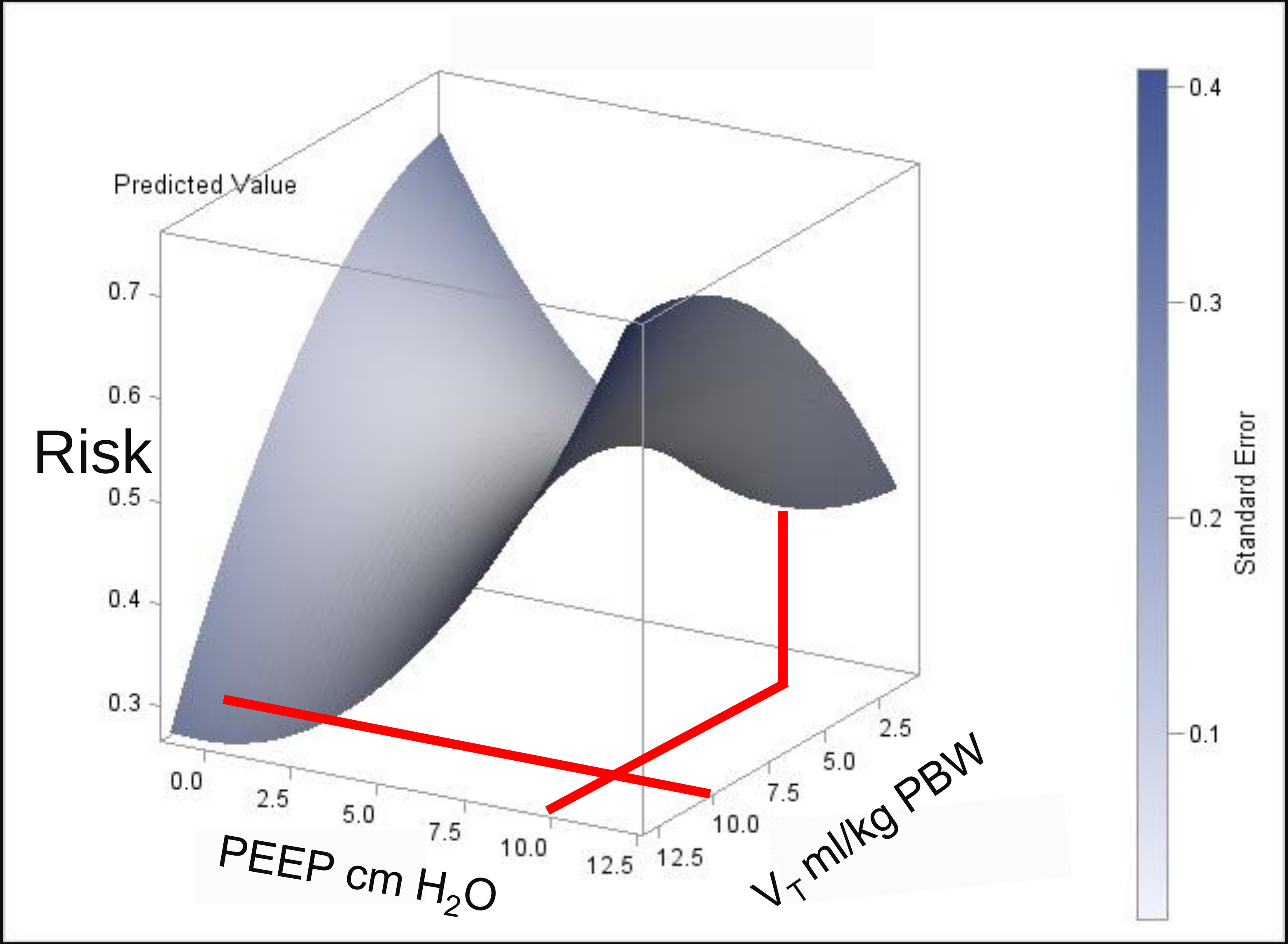
Complications by Year



Aim 2

- To assess the interaction between ventilator parameters to determine a “best” combination of V_T and PEEP during 1LV for minimizing postoperative complication rate


P = 0.718
Predicted Probability of
Postoperative Pulmonary Complications
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1
2
3
4
5
6
7
8
9
10
11
Tidal Volume (mL/kg [PBW])


Predicted Value
0.7
0.6
Risk
0.5
0.4
0.3
0.0
2.5
5.0
7.5
10.0
12.5
PEEP cm H_2O
2.5
5.0
7.5
10.0
12.5
V_T ml/kg PBW
0.4
0.3
0.2
0.1
Standard Error

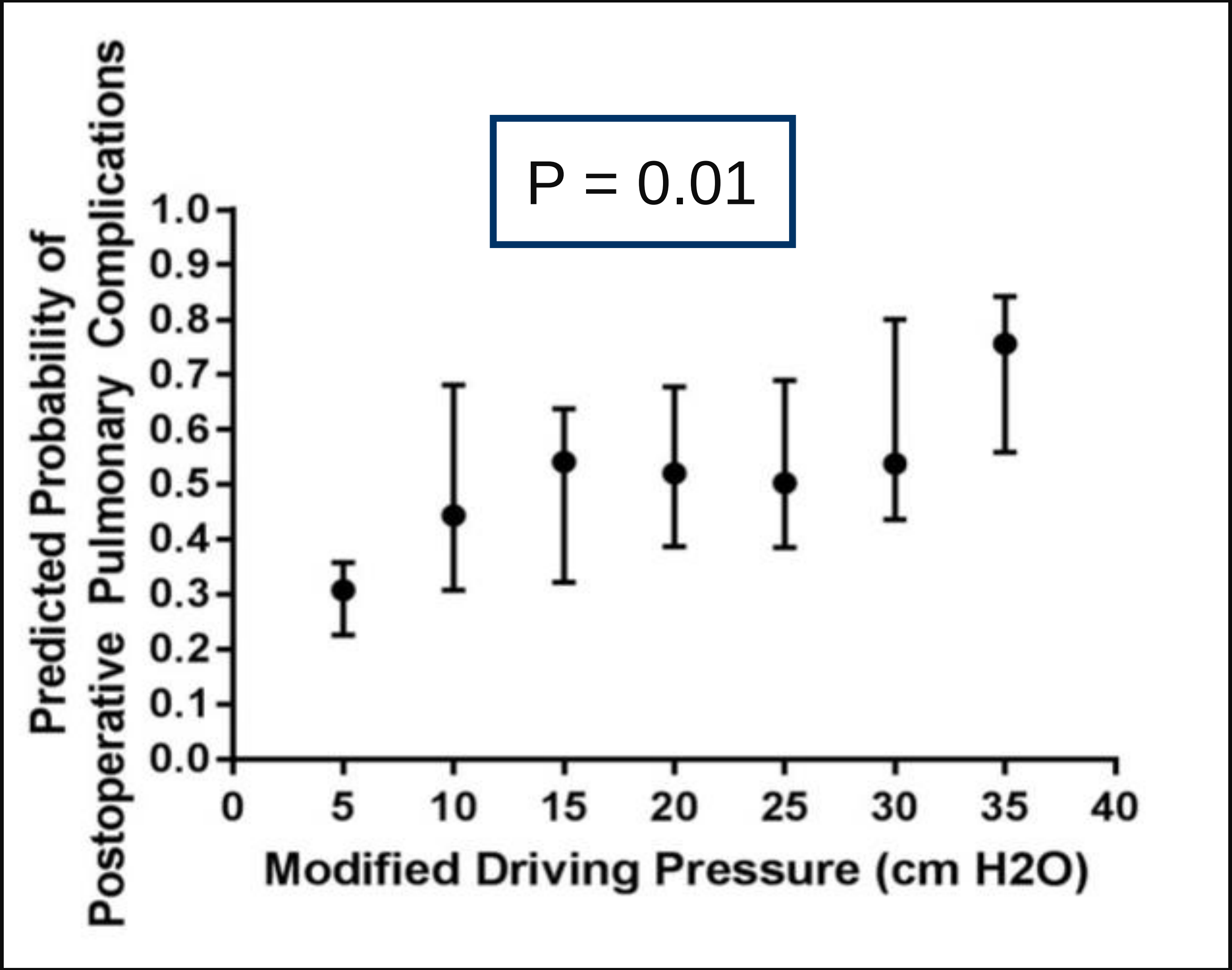
Aim 3

- To determine whether ventilatory correlates of dynamic alveolar strain – notably ΔP (P_{plat}-PEEP) or $m\Delta P$ are predictive of postoperative complications

Driving Pressure and Complications

Pper 1 cm H_2O

	Respiratory Complications		Morbidity		Morbidity and Mortality	
	Adjusted Odds (95% CI)	P-value	Adjusted Odds (95% CI)	P-value	Adjusted Odds (95% CI)	P-value
Modified Driving Pressure	1.03 (0.99, 1.08)	0.156	**1.05** (1.01, 1.09)	0.021	**1.06** (1.01, 1.10)	0.021
Peak Inspiratory Pressure	1.03 (0.99, 1.07)	0.152	**1.05** (1.01, 1.09)	0.012	**1.06** (1.02, 1.10)	0.003


P = 0.01
Predicted Probability of Postoperative Pulmonary Complications
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
25
30
35
40
Modified Driving Pressure (cm H2O)

Conclusions

- LPV – as currently defined
  - not ideally protective
- Low V_T not inherently protective
- ΔP predicts complications
- Large database studies integrating
  - Intraoperative (ventilation)
  - Postoperative (outcome)
  - Role/interaction of V_T, PEEP, P_{aw}
- 3D surface plot analysis

Acknowledgements

MPOG

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MPOG PI

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Anesth Analg 2017; 125: 1922


Thank You
University of Virginia Health System

Respiratory Complications

	Total (N = 1220)	No LPV (n = 610)	LPV (n = 610)	P-Value
ARDS	4 (0.3)	2 (0.3)	2 (0.3)	0.999
Air leak > 5 days	76 (6.2)	46 (7.5)	30 (4.9)	0.041
Atelectasis	53 (4.3)	21 (3.4)	32 (5.2)	0.131
Bronchopleural Fistula	2 (0.2)	2 (0.3)	0 (0.0)	N/A
Pneumonia	42 (3.4)	20 (3.3)	22 (3.6)	0.758
Pneumothorax	28 (2.3)	14 (2.3)	14 (2.3)	0.999
Other pulmonary event	22 (1.8)	10 (1.6)	12 (2.0)	0.670
Pulmonary embolism	6 (0.5)	3 (0.5)	3 (0.5)	0.999
Respiratory failure	36 (3.0)	19 (3.1)	17 (2.8)	0.739
Tracheostomy	11 (0.9)	7 (1.1)	4 (0.7)	0.366
Ventilator support > 48 hours	11 (0.9)	6 (1.0)	5 (0.8)	0.763
Total		16%	16%	0.816

Protective Ventilation
Meta Analysis 15 Trials, N=2127

Outcome	RR	p Value
PPC	0.64	< 0.01
ARDS	0.45	0.01
Barotrauma	0.39	0.03

Serpa Neto et al. Anesthesiology 2015; 123: 66-78

Protective Ventilation
Meta Analysis 15 Trials, N=2127

32% 6.6 X

	Median V_T ml/kg
Protective	7.3
Conventional	10.8

Serpa Neto et al. Anesthesiology 2015; 123: 66-78

Ventilation Data (MPOG)

V_T ABW, PBW
PEEP
PIP
P_{aw}
P_{plat}

RR
Vent mode
FIO_2
$ETCO_2$

$\Delta P = P_{PLAT} - PEEP$
$m\Delta P = PIP - PEEP$

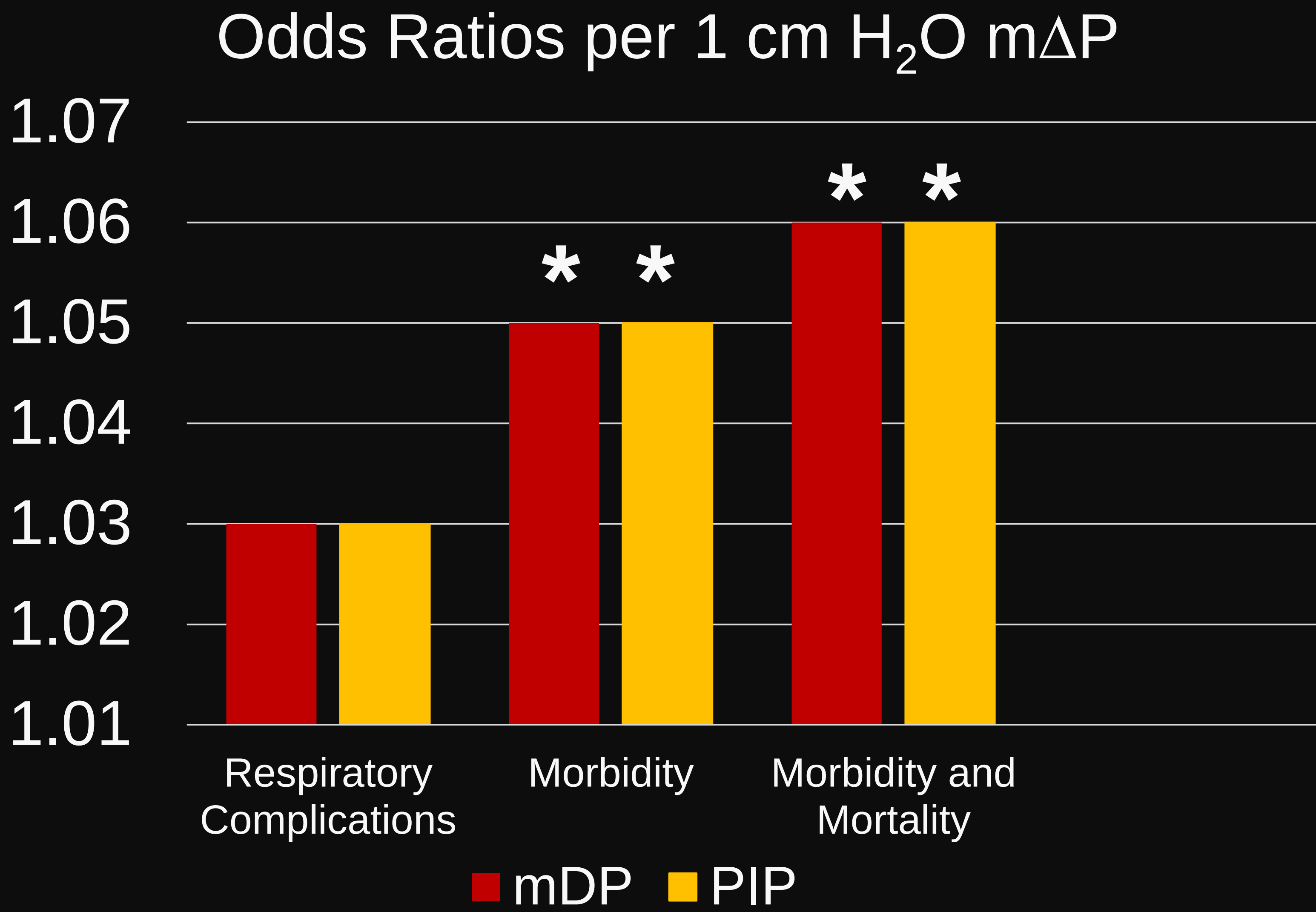
STS Thoracic Database

Baseline Patient, Procedural

- Age at surgery
- Female sex
- BMI (kg/m^2)
- Zubrod score
- ASA status
- Renal dysfunction
- Current smoker
- Induction chemotherapy or radiation
- Preoperative steroid therapy
- FEV_1 (% predicted)
- Major preoperative morbidity
- Blood product transfusion
- VATS
- Thoracotomy
- Other approach
- Wedge resection
- Bilobectomy/pneumonectomy
- Esophageal procedure
- Lung transplantation
- Pleura/diaphragm/mediastinal/chest wall
- Segmentectomy/lobectomy
- Other thoracic procedure

Outcomes, Complications

- Tracheostomy
- Empyema requiring treatment
- Pneumonia
- Reintubation
- Initial ventilator support > 48 h
- ARDS
- Bronchopleural fistula
- Pulmonary embolus
- Air leak > 5 days
- Atelectasis requiring bronchoscopy
- Respiratory failure
- Unexpected return to operating room
- Atrial arrhythmia requiring treatment
- Ventricular arrhythmia requiring treatment
- Myocardial infarction
- Anastomotic failure requiring treatment
- Sepsis
- Central neurologic event
- Renal failure
- Unexpected ICU admission
- Mortality within 30 days
- Primary outcome
- Secondary outcome



Odds Ratios per 1 cm H_2O mΔP
1.07
1.06
1.05
1.04
1.03
1.02
1.01
*
*
*
*
Respiratory Complications
Morbidity
Morbidity and Mortality
mDP
PIP

Aim 4

- To determine whether patients known to be at higher risk for receiving high V_T/kg PBW – patients with high BMI, short stature, and female gender - are more likely to be subjected to ventilator regimens associated with higher levels of ΔP

- Whether these patients are at higher risk for postoperative complications

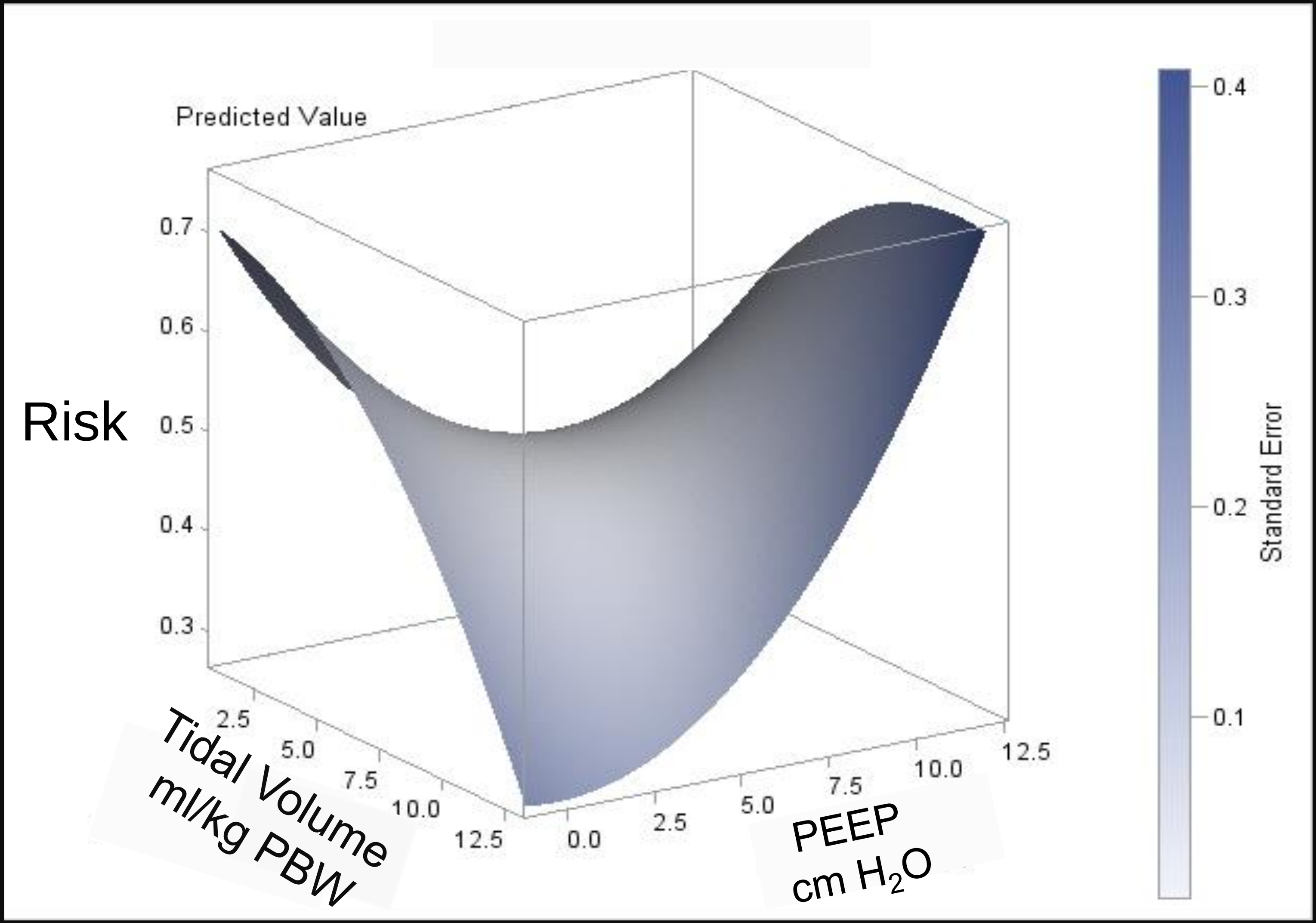
- Mixed effects logistic regression modeling

Results

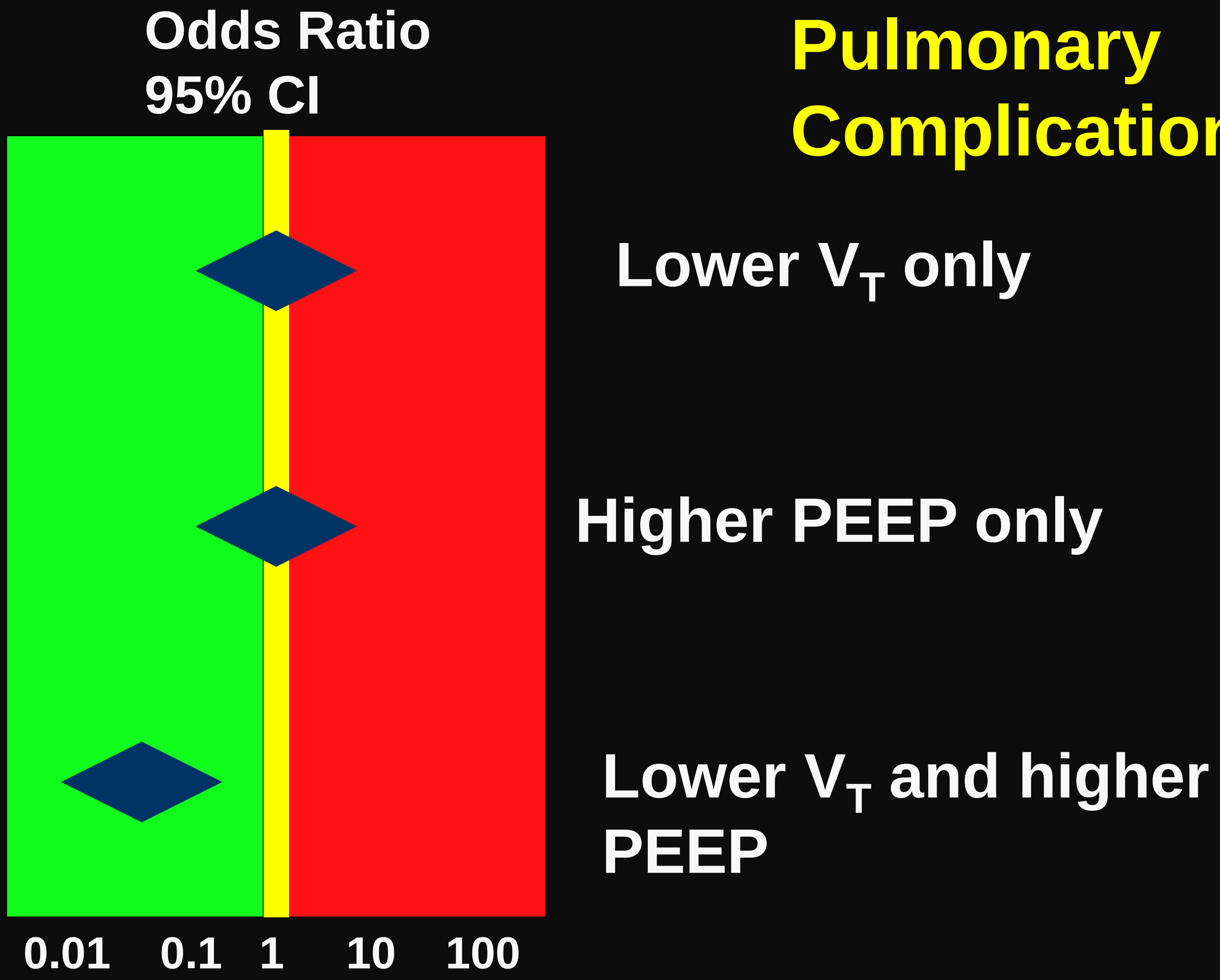
	B Coefficient (Std. Err.)	P-Value
BMI	0.32 (0.02)	<0.001
Height (cm)	0.01 (0.02)	0.712
Female Sex	-0.56 (0.35)	0.116

Results

	Respiratory Complications		Morbidity and Respiratory Complications		Morbidity, Respiratory Complications, and Mortality	
	Adjusted Odds (95% CI)	P-value	Adjusted Odds (95% CI)	P-value	Adjusted Odds (95% CI)	P-value
BMI	0.99 (0.95, 1.03)	0.625	1.01 (0.98, 1.05)	0.507	1.01 (0.97, 1.04)	0.728
Height (cm)	0.98 (0.95, 1.01)	0.132	0.98 (0.95, 1.00)	0.088	0.98 (0.95, 1.01)	0.115
Female Sex	2.35 (1.08, 5.10)	0.031	1.38 (0.72, 2.64)	0.326	1.25 (0.66, 2.39)	0.494


Predicted Value
Risk
0.7
0.6
0.5
0.4
0.3
Tidal Volume ml/kg PBW
2.5
5.0
7.5
10.0
12.5
0.0
2.5
5.0
7.5
10.0
12.5
PEEP cm H_2O
Standard Error
0.4
0.3
0.2
0.1

Pulmonary Complications



MPOG Perioperative Data

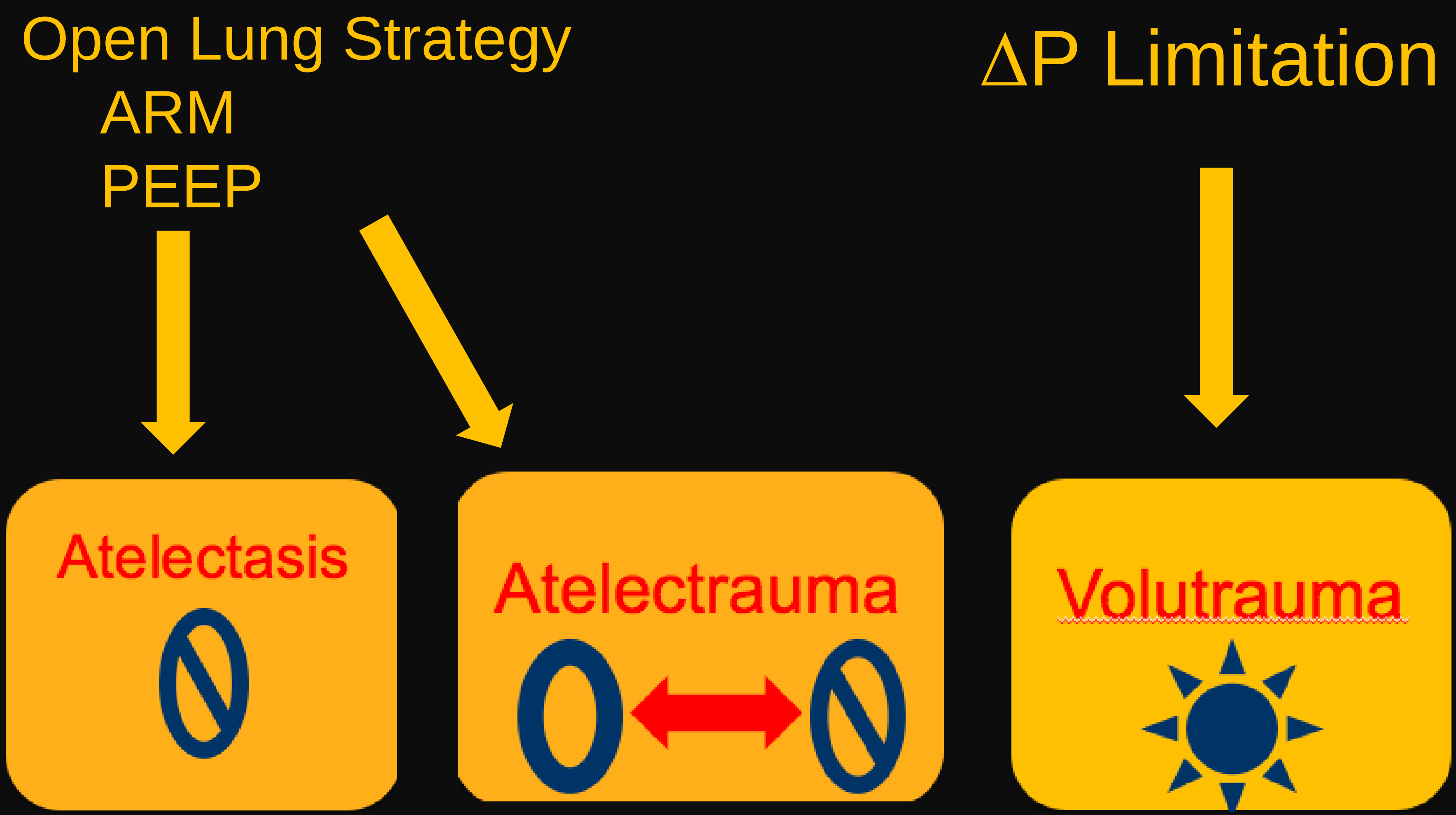
- **Intraoperative Data**
  - Medications, fluids, blood products
  - Physiologic monitoring, ventilator management
  - Procedure/case times
- **Additional Perioperative Data**
  - Lab values – 365 days before/after surgery
  - Anesthesia H&P – some additional concepts
  - Billing/lab-based outcomes data

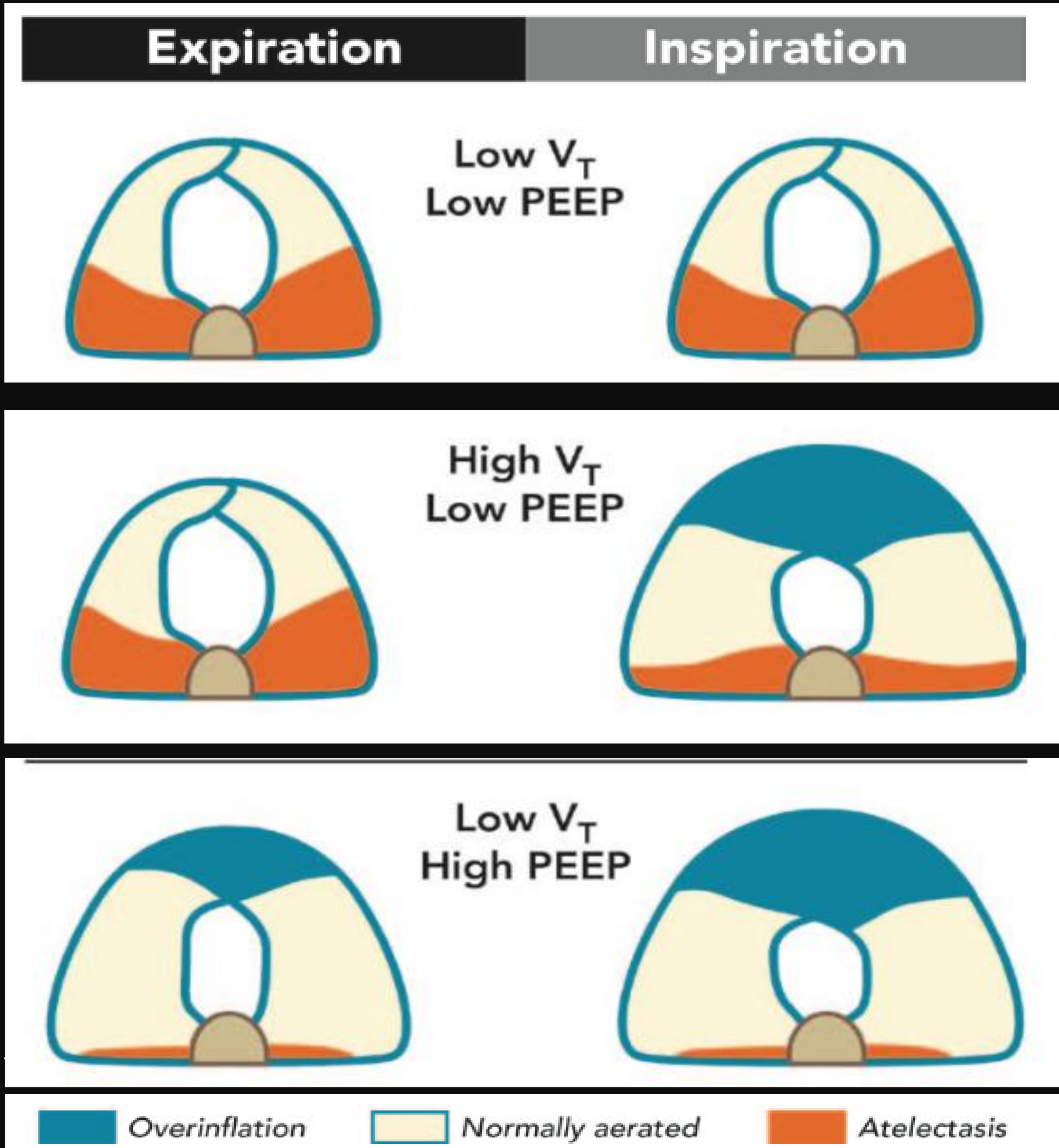
STS Thoracic Database

- Strengths of STS
  - **Outcomes** (verified by site data managers)
  - **Comorbidities** (also verified)
  - Preoperative testing
  - Established national standard, 281 sites


Tidal Volume
Atelectasis
PEEP

PPCs in Surgical Patients





Atelectasis

Overinflation
Tidal recruitment

Overinflation

Guldner et al. Anesthesiology 2015; 123:692-713

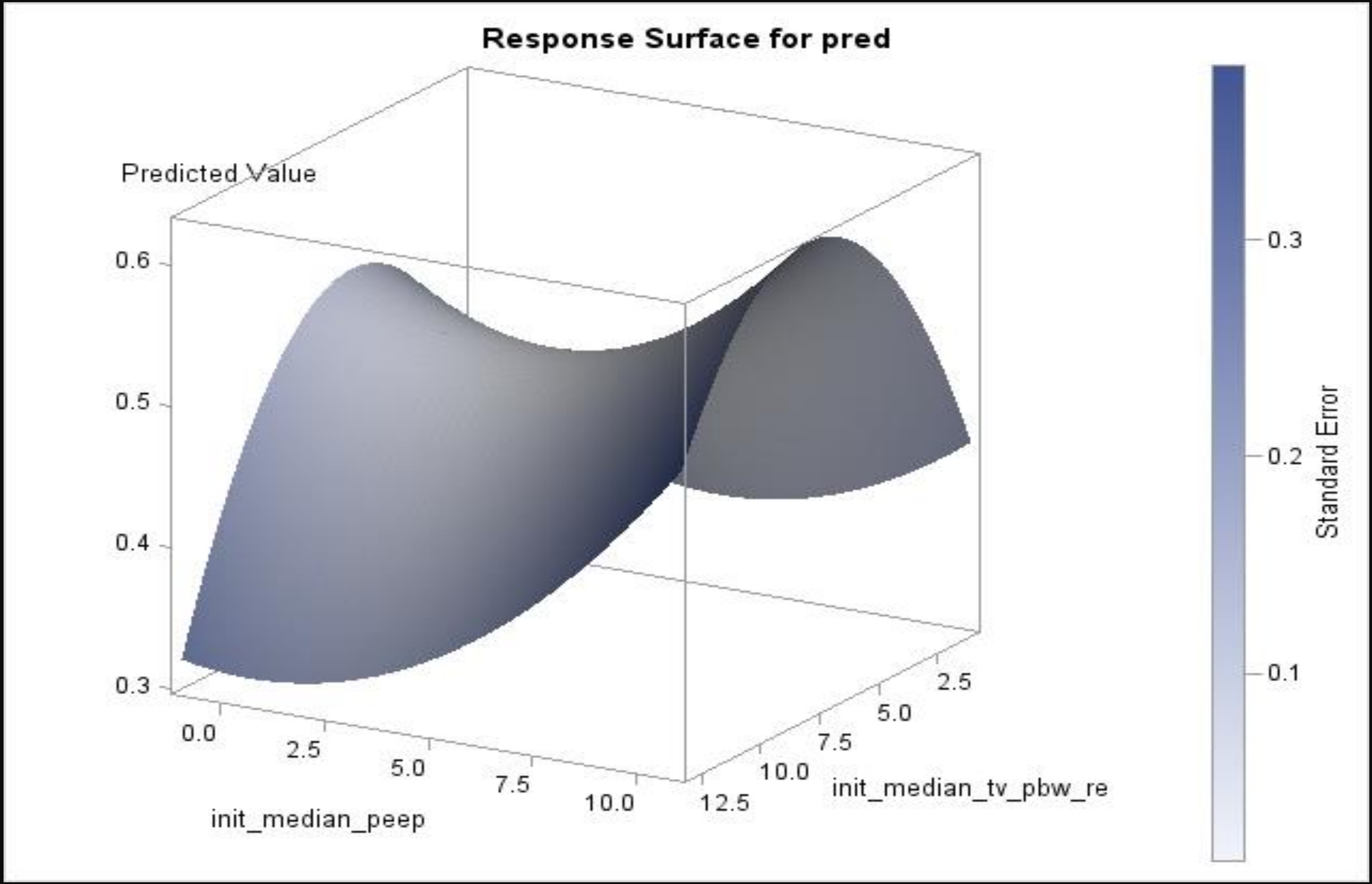
Standardizing V_T

- Lung volume data not routinely available for surgical patients
- Need measure of functional lung volume
  - Relative to delivered V_T
  - Easily measured in surgical patients
- Airway driving pressure
  - Ability of lung parenchyma to accommodate V_T
  - ΔP predicts adverse outcomes

Anesth Analg 2017; 125: 1922

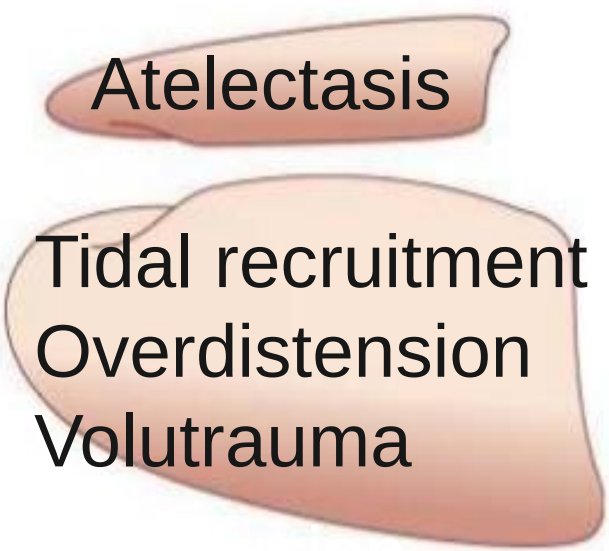
Study	Subjects	Parameter	Conclusion
Br J Anaesth 2015:114;483	ASA 1-3 Excluding COPD	Intratidal compliance	PEEP = 5 insufficient to prevent derecruitment
Anesth Analg 2008;106:175	ASA 1-2, healthy lungs	Compliance, dead space fraction	Optimal PEEP = 10
Acta Anaesthesiol Scand 2006; 50: 833	Morbid obesity BMI 49±8	Electrical impedance tomography	Optimal PEEP = 15
Br. J Anaesth 2017;119:1194	Obesity BMI ≥ 35	Electrical impedance tomograpy	Individualized mean PEEP = 18.5
Anesthesiology 2018; 128: 531	OLV	Mechanics -P/F, shunt, ΔP	PEEP = 10
Lancet Resp Med 2018; 6: 193	Elevated risk PPC	Clinical outcomes	PEEP > 10 when individualized

Aim 2 – Morbidity



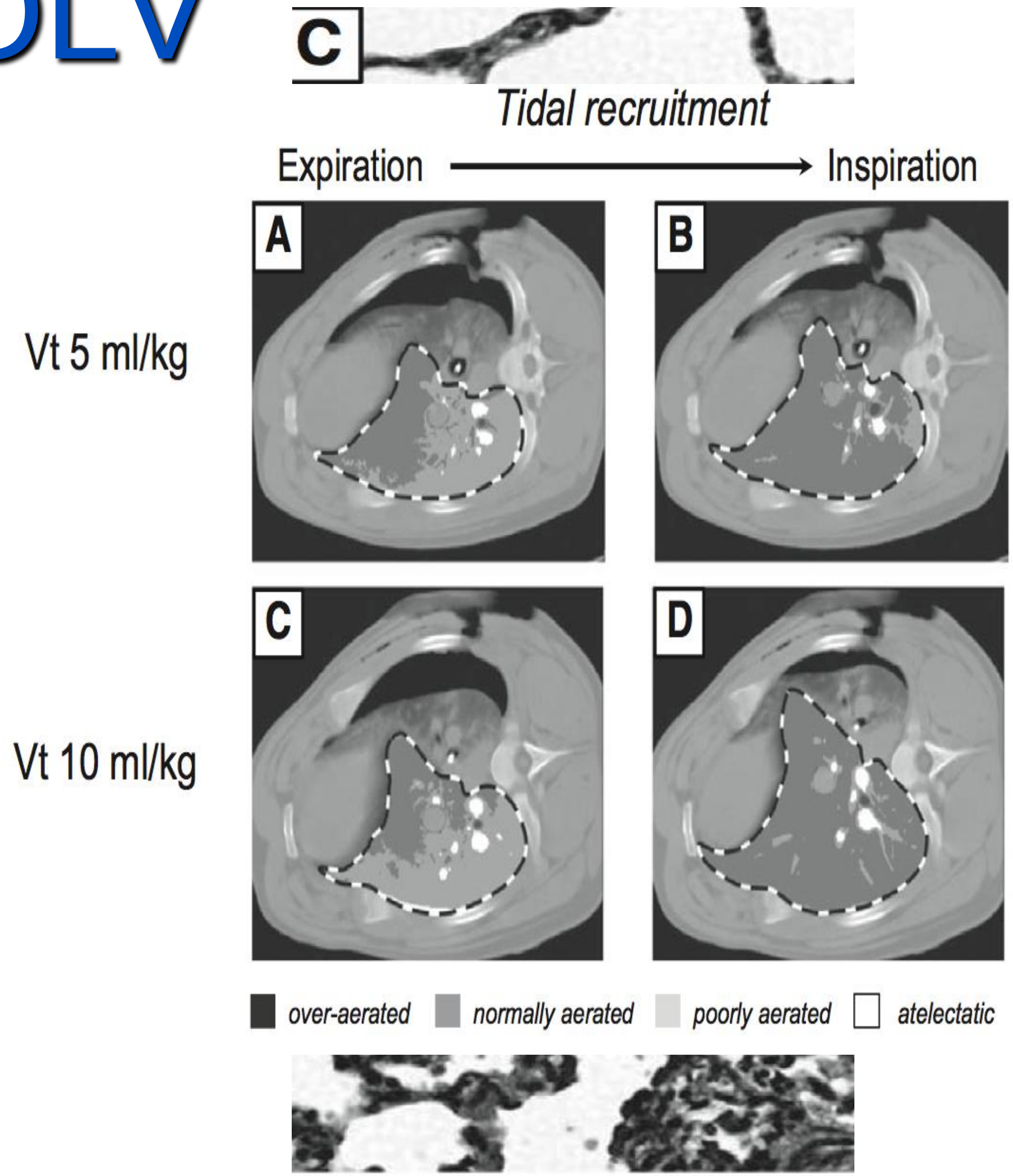
VILI during OLV

Reexpansion
I/R injury



Atelectasis

Tidal recruitment
Overdistension
Volutrauma

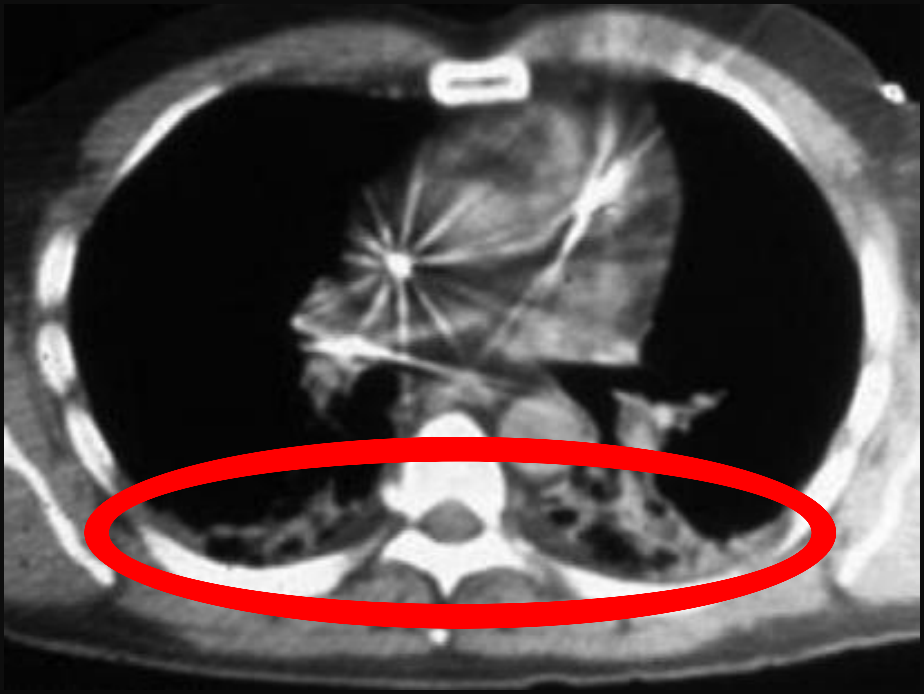


Capillary shear stress

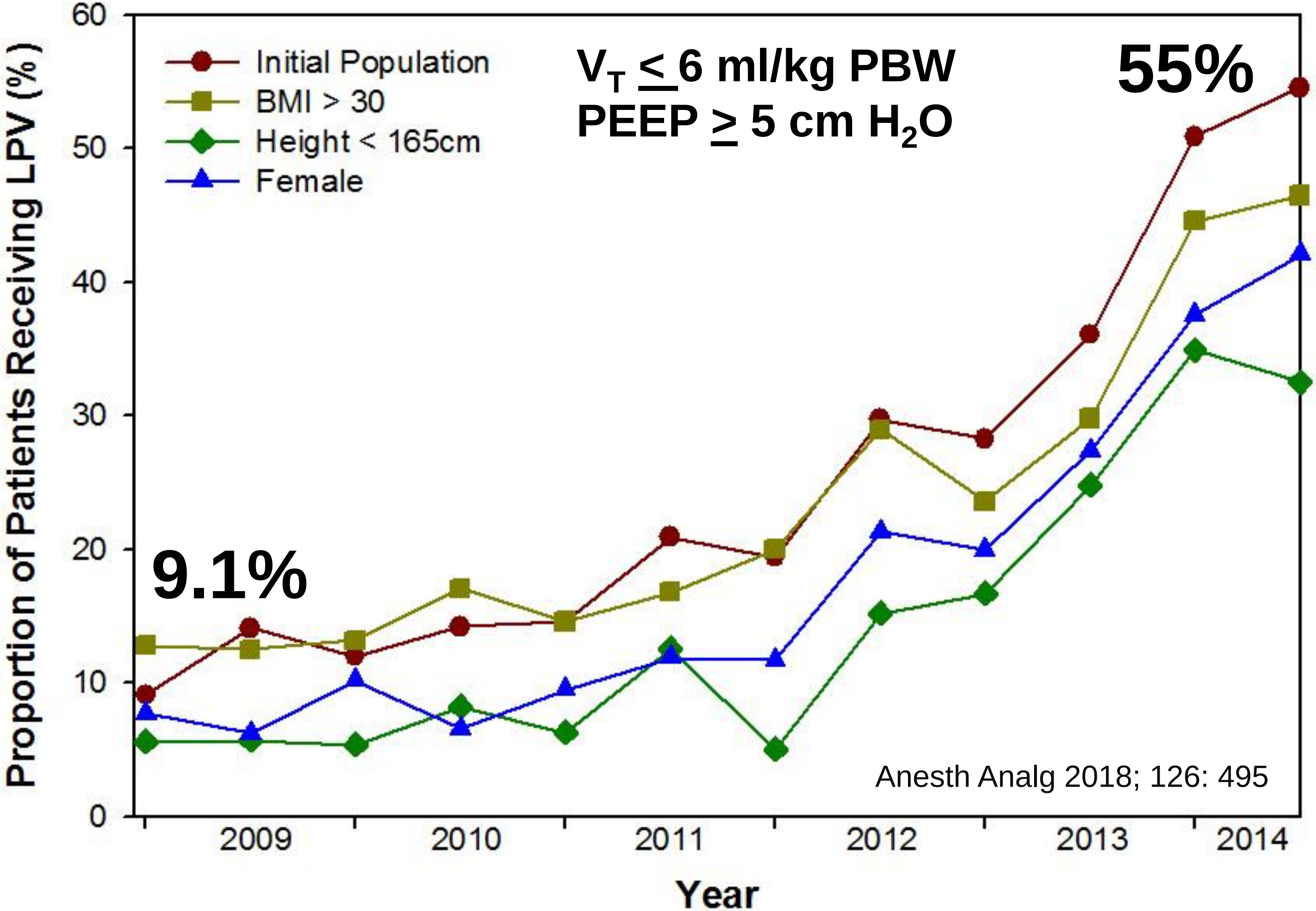
Anesth Analg 2015; 121: 302

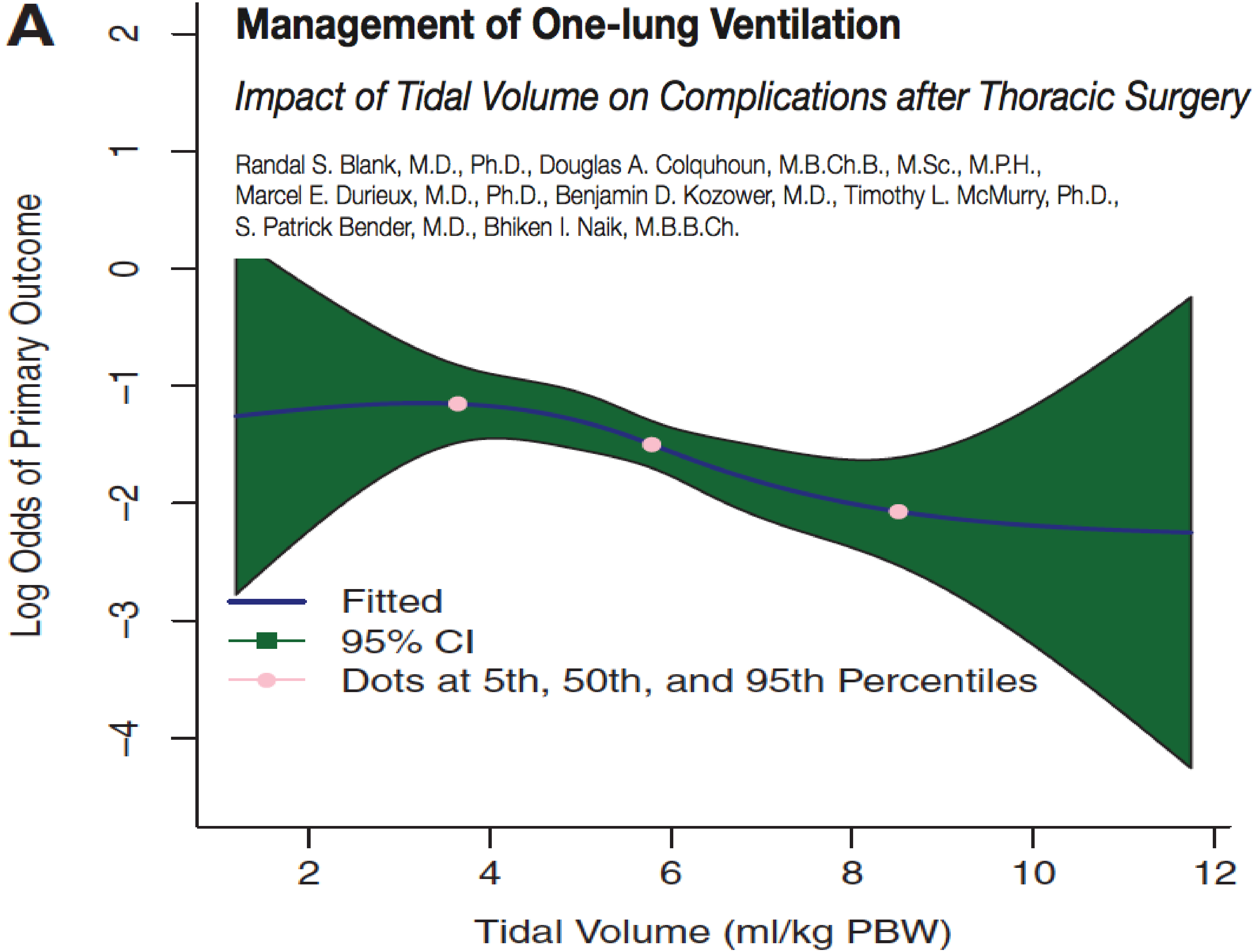
What do we know about LPV?

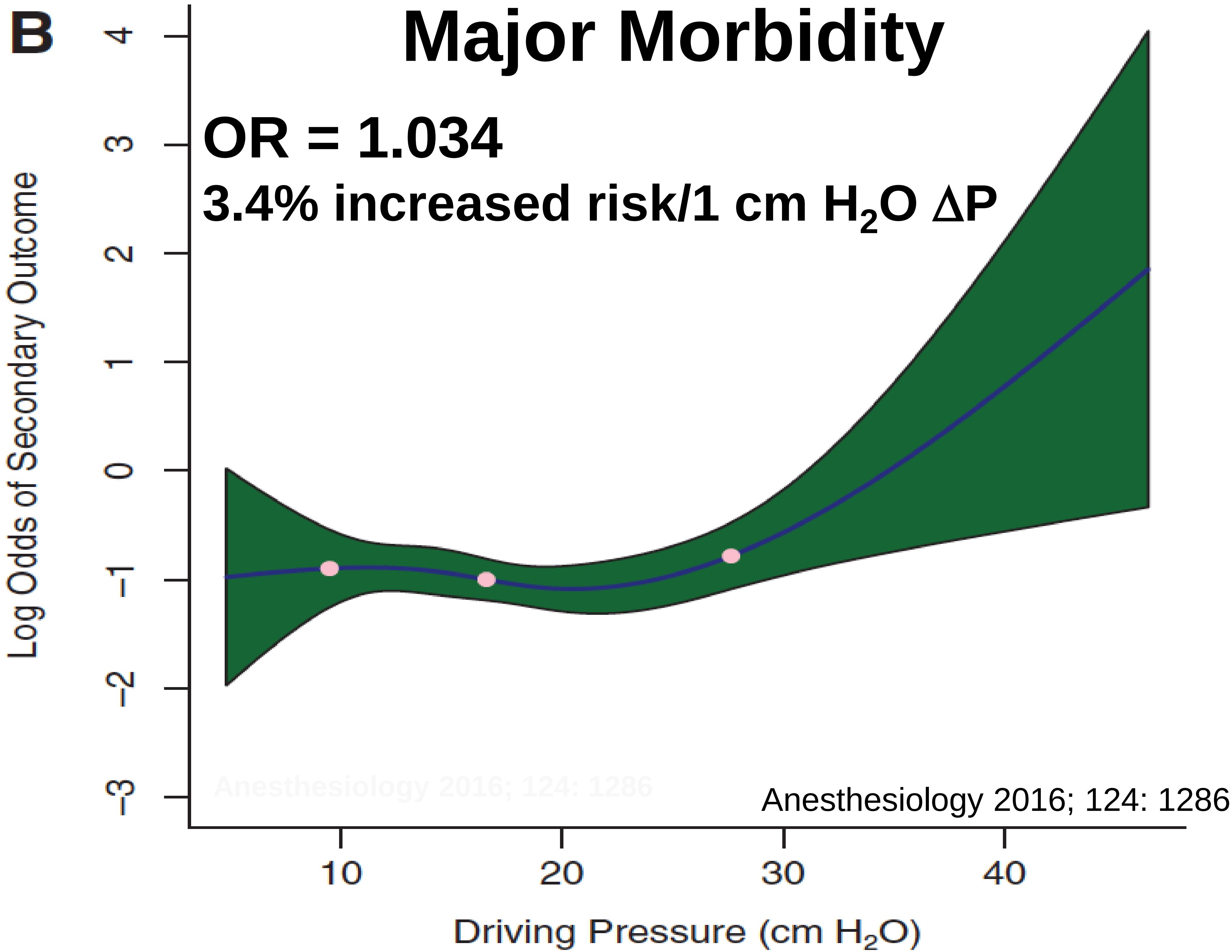
- Supraphysiologic V_T and ZEEP is harmful
- Physiologic V_T, moderate PEEP better
- Low V_T not protective per se



Lung Protective 1LV




A
Management of One-lung Ventilation
Impact of Tidal Volume on Complications after Thoracic Surgery
Randal S. Blank, M.D., Ph.D., Douglas A. Colquhoun, M.B.Ch.B., M.Sc., M.P.H.,
Marcel E. Durieux, M.D., Ph.D., Benjamin D. Kozower, M.D., Timothy L. McMurry, Ph.D.,
S. Patrick Bender, M.D., Bhiken I. Naik, M.B.B.Ch.
Log Odds of Primary Outcome
2
1
0
−1
−2
−3
−4
Fitted
95% CI
Dots at 5th, 50th, and 95th Percentiles
2
4
6
8
10
12
Tidal Volume (ml/kg PBW)


B
Major Morbidity
OR = 1.034
3.4% increased risk/1 cm H2O ΔP
Log Odds of Secondary Outcome
4
3
2
1
0
−1
−2
−3
10
20
30
40
Driving Pressure (cm H2O)
Anesthesiology 2016; 124: 1286