Lung protection & Aveolar recruitment during lung isolation

Dr. Thao Giang, Heart Center,

Vietnam National Children's Hospital

No Conflict of Interest

Outline

1. Intraoperative PLV & one-lung ventilation
    - what’s make it different
2. Mechanism of injuries in Lung Isolation
    - Ventilated lung & deflated lung
    - How to mitigate
3. PLV and ARM
    - unseparated couple

Intraoperative- Protective Lung Ventilation

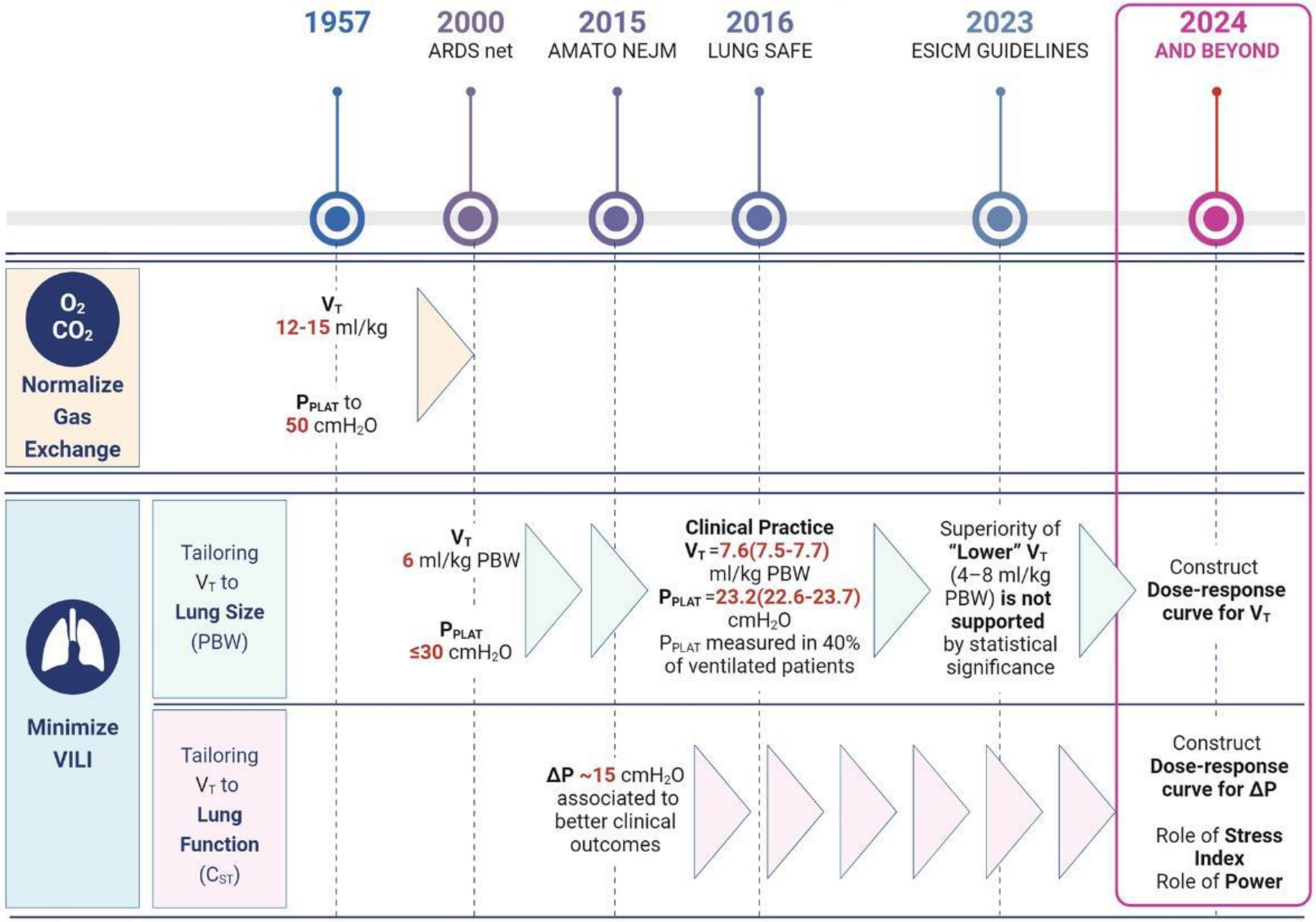
- Cyclic tidal overdistention causing VILI
- Atelectrauma is the most concern

(not volume trauma or barotrauma as ARDS)

- Diaphragm dysfunction (atrophy)
- Surgical manipulation

01

From: Finding the optimal tidal volume in acute respiratory distress syndrome



Timetable reporting changes of evidence guiding V_T and airway pressure settings to ensure proper mechanical ventilation in ARDS. The timetable goes from 1957, when ARDS was first defined until today. Abbreviations: *ARDS* acute respiratory distress syndrome, C_{RS} compliance of the respiratory system, C_{ST} static compliance, *ΔP* driving pressure, P_{PLAT} plateau pressure, *PBW* predicted body weight, V_T tidal volume

Pellegrinin, 2024: Intensive care Medecine

Intraoperative- Protective Lung Ventilation

PIP	**= Flow x resistance + Pav**
Resistance	**= (PIP – Pplateau)/Vi**
P mean	**= 0,5 x (PIP–PEEP) x (Tisp/Ttotal) + PEEP**
P plateau	**= (Vt/Compliance) + PEEP**

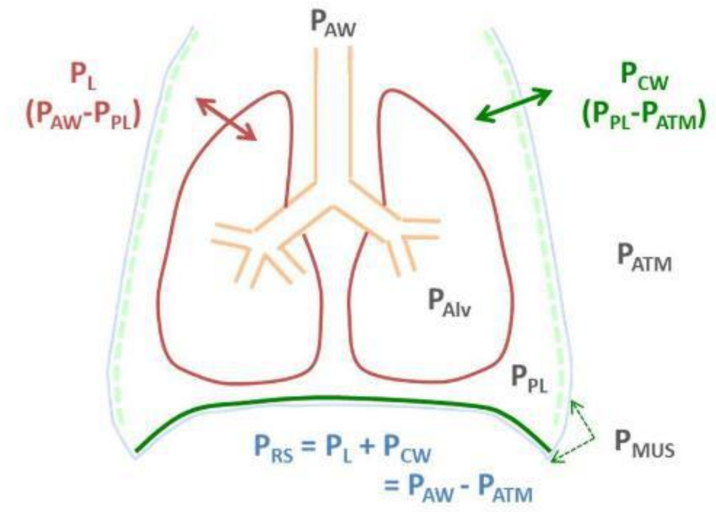


Figure 1 Schematic representation of the relationship between structures within the respiratory system. According to the equation of motion of the respiratory system. $P_{TOT}=P_{AW} + _{PMUS}$ (1). $P_{TOT} = P_0+E_{RS}*V+R_{RS}*V'$ (2). since $P_{RS}=P_L + _{PCW}$, $E_{RS}=E_L + _{ECW}$ and the final equation can be written as. $p_{AW} +P_{MUS} = P_0+E_{CW}*V+E_L*V+R_{RS}*V'$ (3). E_{CW}, chest wall elastance; E_L, lung elastance; E_{RS}, respiratory system elastance; P_{ATM}, atmospheric pressure; P_{AW}, airways pressure; P_0, p_{AW} at the beginning of the ventilatory cycle; P_{CW}, pressure difference across the chest wall; P_L, transpulmonary pressure; P_{MUS}, respiratory muscles' generated-pressure; P_{PL}, pleural pressure; P_{RS}, pressure difference across the respiratory system; P_{TOT}, total pressure applied to the respiratory system; V, air volume; V', airflow.

$$\Delta P = \text{Pplat} - \text{PEEP} \;\rightarrow\; \text{Crs} = \frac{\text{TV}}{\Delta P} \;\rightarrow\; \Delta P = \frac{\text{TV}}{\text{Crs}}$$

VedrenneCloquet M, Khirani S, Khemani R, et al. Thorax 2023;78:97–105.

Intraoperative- Protective Lung Ventilation

ANESTHESIOLOGY

Driving Pressure during Thoracic Surgery

A Randomized Clinical Trial

MiHye Park, M.D., Hyun Joo Ahn, M.D., Ph.D., Jie Ae Kim, M.D., Ph.D., Mikyung Yang, M.D., Ph.D., Burn Young Heo, M.D., Ph.D., Ji Won Choi, M.D., Ph.D., Yung Ri Kim, M.D., Sang Hyun Lee, M.D., Ph.D., HeeJoon Jeong, M.D., Soo Joo Choi, M.D., Ph.D., In Sun Song, M.D.

(ANESTHESIOLOGY 2019; 130:385–93)

ABSTRACT

Background: Recently, several retrospective studies have suggested that pulmonary complication is related with driving pressure more than any other ventilatory parameter. Thus, the authors compared driving pressure–guided ventilation with conventional protective ventilation in thoracic surgery, where lung protection is of the utmost importance. The authors hypothesized that driving pressure–guided ventilation decreases postoperative pulmonary complications more than conventional protective ventilation.

Methods: In this double-blind, randomized, controlled study, 292 patients scheduled for elective thoracic surgery were included in the analysis. The protective ventilation group (n = 147) received conventional protective ventilation during one-lung ventilation: tidal volume 6 ml/kg of ideal body weight, positive end-expiratory pressure (PEEP) 5 cm H_2O, and recruitment maneuver. The driving pressure group (n = 145) received the same tidal volume and recruitment, but with individualized PEEP which produces the lowest driving pressure (plateau pressure–PEEP) during one-lung ventilation. The primary outcome was postoperative pulmonary complications based on the Melbourne Group Scale (at least 4) until postoperative day 3.

Conventional PLV:

FiO2 100%
Vt=6ml/kg
PEEP= 5
Tins pause 30%
I:E=1:2
↕ RR

ΔP guided

↗PEEP from 2- 10 cm H2O
Vt=6m;/kg
PEEP=5
RR=12

PEEP level that produced the lowest driving pressure was chosen and maintained throughout one-lung ventilation

Results: PPCs= 8/145 patients (5.5%) in **ΔP** group, 18 of 147 (12.2%) in the **PLV** group (P = 0.047, odds ratio 0.42; 95% CI, 0.18 to 0.99).

What're we doing

Use of lung-protective strategies during one-lung ventilation surgery: a multi-institutional survey

Biniam Kidane[1,2], Stephen Choi[3], Dalilah Fortin[1,4,5], Turlough O'Hare[6], George Nicolaou[7], Neal H. Badner[7], Richard I. Inculet[1,4], Peter Slinger[3], Richard A. Malthaner[1,4]

[1]Department of Surgery, Western University, London, Ontario, Canada; [2]Department of Surgery, University of Manitoba, Winnipeg, Manitoba, Canada; [3]Department of Anesthesia, University of Toronto, Toronto, Ontario, Canada; [4]Division of Thoracic Surgery, Department of Surgery, [5]Division of Critical Care Medicine, Department of Medicine, Western University, London, Ontario, Canada; [6]Department of Anesthesia, McMaster University, Hamilton, Ontario, Canada; [7]Department of Anesthesia & Perioperative Medicine, Western University, London, Ontario, Canada

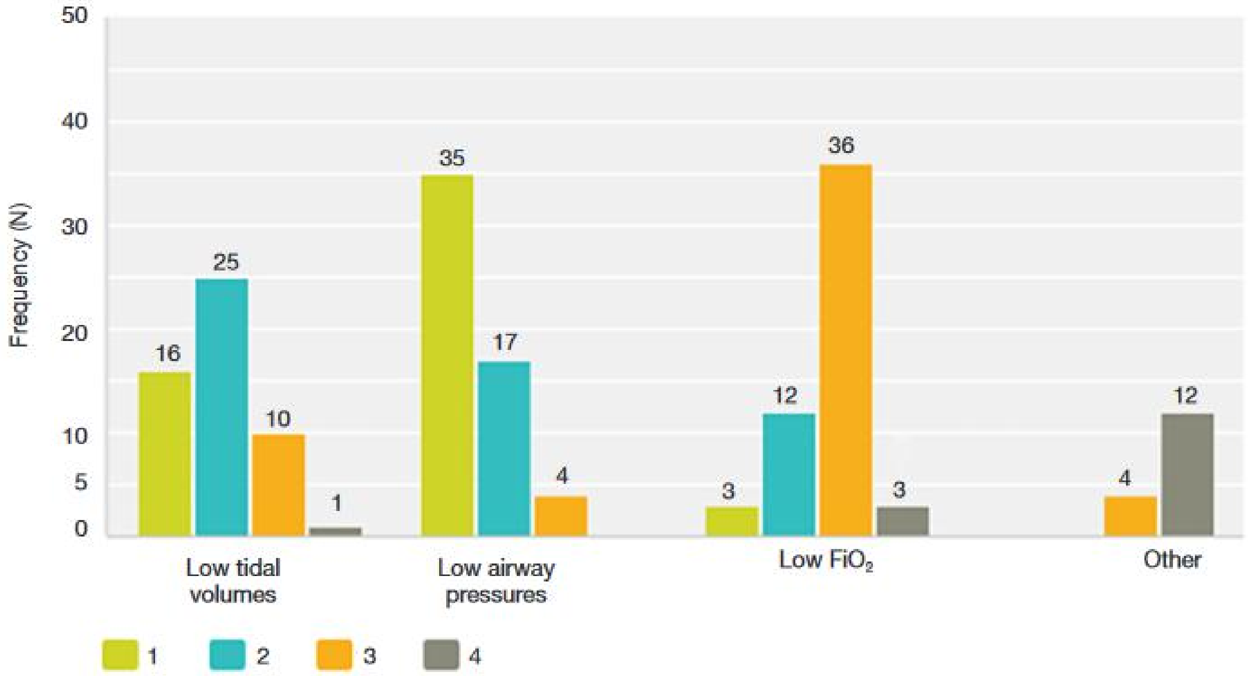
Contributions: (I) Conception and design: All authors; (II) Administrative support: All authors; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: B Kidane, S Choi; (V) Data analysis and interpretation: All authors; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Biniam Kidane. 820 Sherbrook Street, GE-611, Winnipeg, Manitoba, R3A 1R9, Canada. Email: b.kidane@mail.utoronto.ca.

- ✓ **In 2018**, at 3 high volume Canadian tertiary centers
(205-300 cases of lung cancer/year)
- ✓ Survey on anesthesiologists who perform OLV surgeries

Kidane B, Choi S, Fortin D, O'Hare T, Nicolaou G, Badner NH, Inculet RI, Slinger P, Malthaner RA.
Use of lung-protective strategies during one-lung ventilation surgery: a multi-institutional survey. Ann Transl Med 2018;6(13):269. doi: 10.21037/atm.2018.06.02

Results: Seventy-five (63%) of 120 eligible respondents completed the survey. Although the critical care literature focuses on minimizing tidal volume (TV) as the central strategy of LPV, most respondents (89%, n=50/56) focused on minimizing peak airway pressure (PAP) as their primary strategy of intraoperative LPV. Only 64% (n=37/58) reported actively trying to minimize TV. While 32% (n=17/54) were unsure about the current evidence regarding LPV, 67% (n=36/54) believed that the evidence favoured their use during OLV. Perceived clinical and institutional barriers were the only predictors of reduced attempts to minimize TV on univariate analyses. In multivariable/adjusted analyses, perceived institutional barriers were the only predictors of reduced attempts to minimize TV with adjusted odds ratio of 0.1 (95% CI: 0.03–0.6).

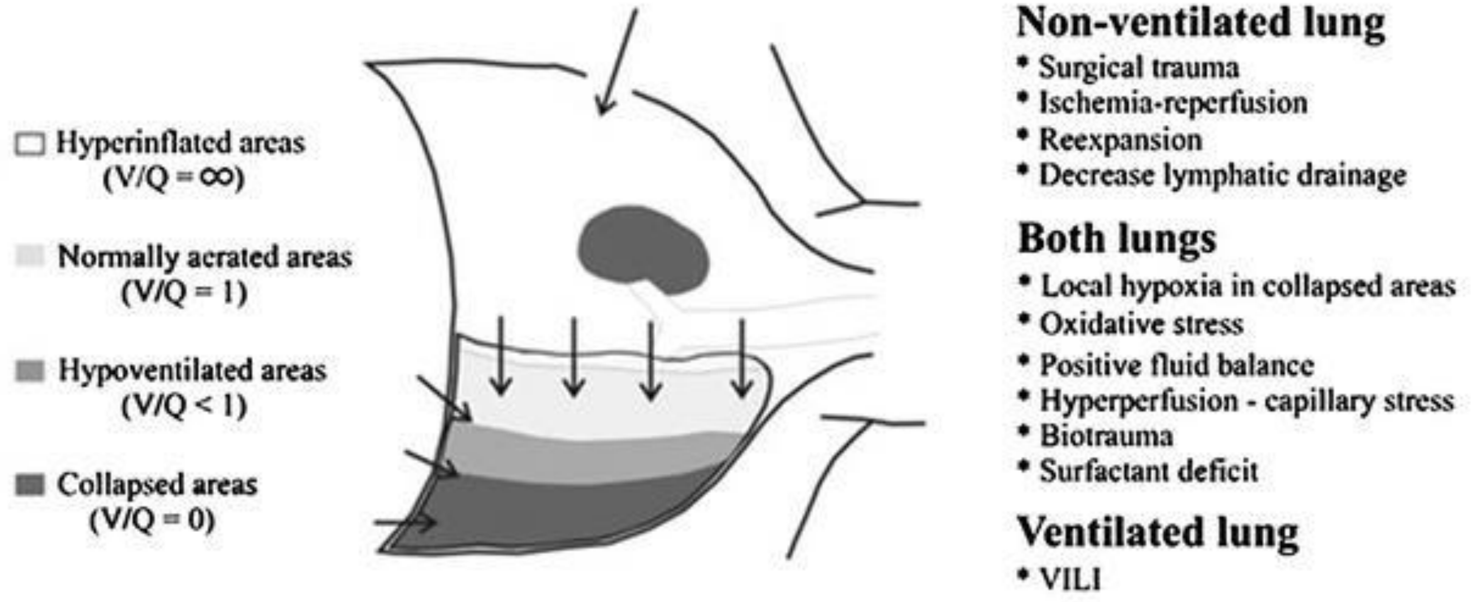


When asked to rate in order of importance what defines LPV, the aggregate order placed minimization of PAP as most important followed by minimization of TV

1-> 4: the most important-> the least important

Lung Isolation

Mechanism of Injuries



Lung Isolation

Mechanism of Injuries

CARDIOVASCULAR ANESTHESIOLOGY: REVIEW ARTICLE

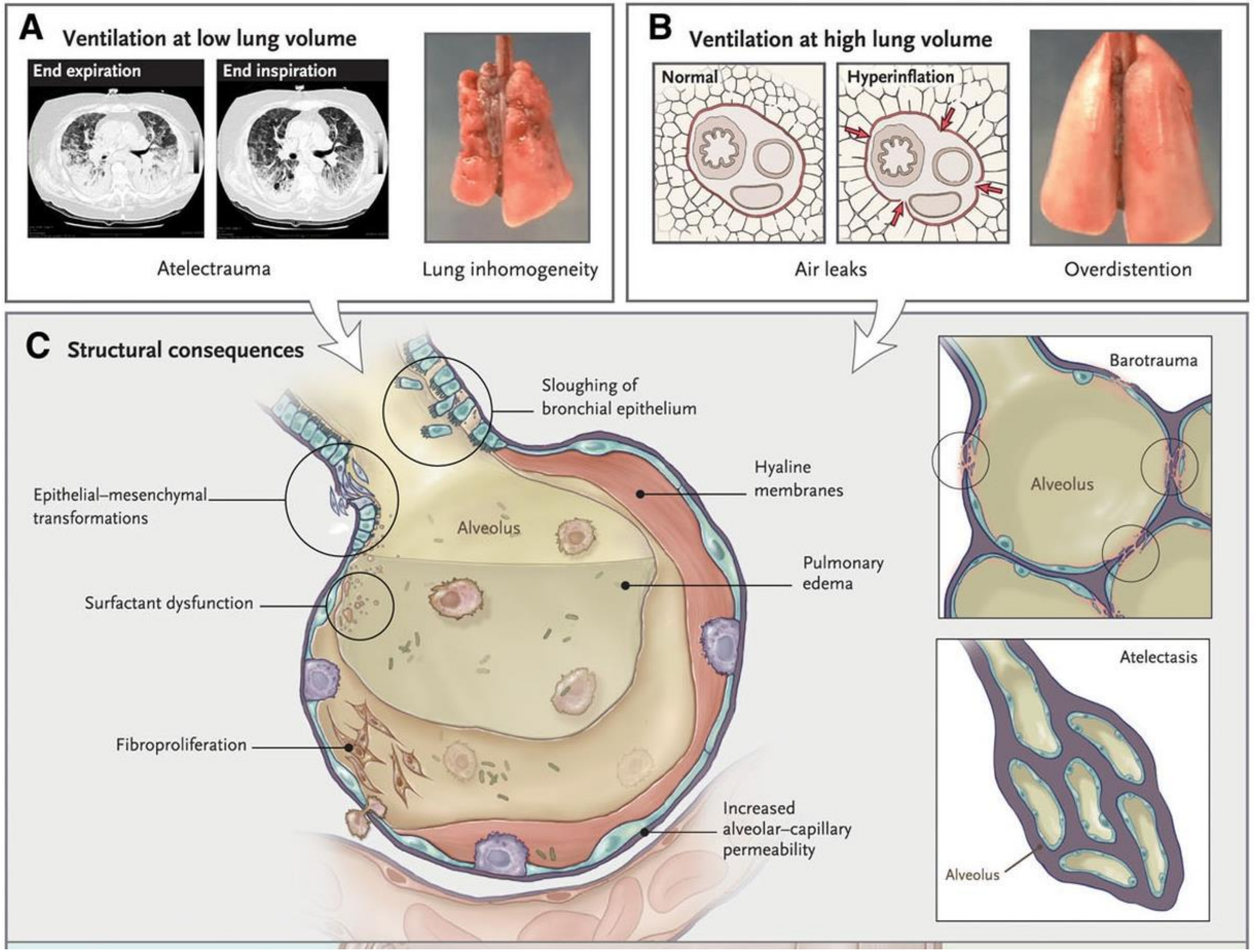
Lung Injury After One-Lung Ventilation

A Review of the Pathophysiologic Mechanisms Affecting the Ventilated and the Collapsed Lung

Lohser, Jens MD, MSc, FRCPC[*]; Slinger, Peter MD, FRCPC[†]

Author Information

Anesthesia & Analgesia 121(2):p 302-318, August 2015. | *DOI:* 10.1213/ANE.0000000000000808



Lung Isolation

Mechanism of Injuries

CARDIOVASCULAR ANESTHESIOLOGY: REVIEW ARTICLE

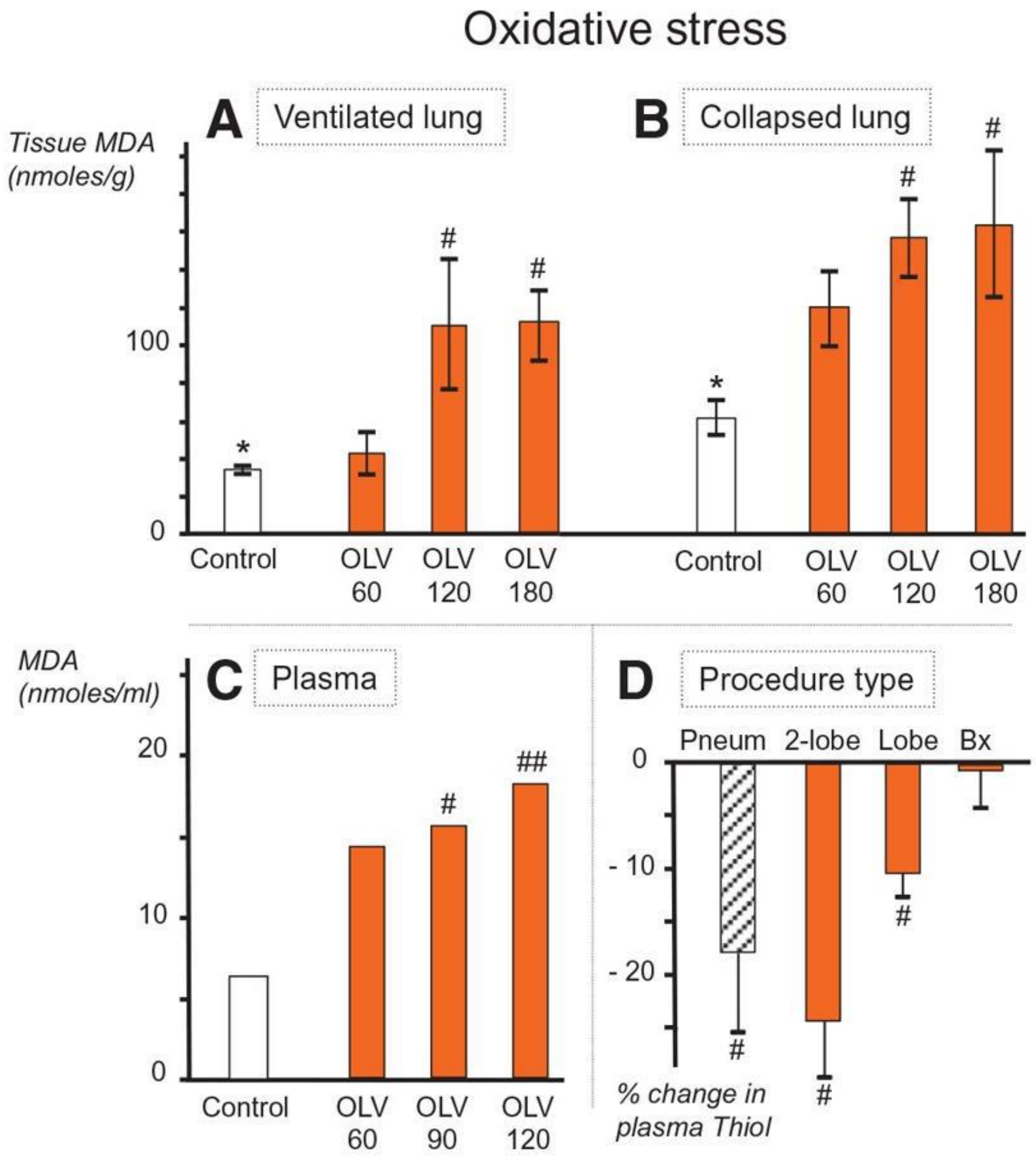
Lung Injury After One-Lung Ventilation

A Review of the Pathophysiologic Mechanisms Affecting the Ventilated and the Collapsed Lung

Lohser, Jens MD, MSc, FRCPC[*]; Slinger, Peter MD, FRCPC[†]

Author Information

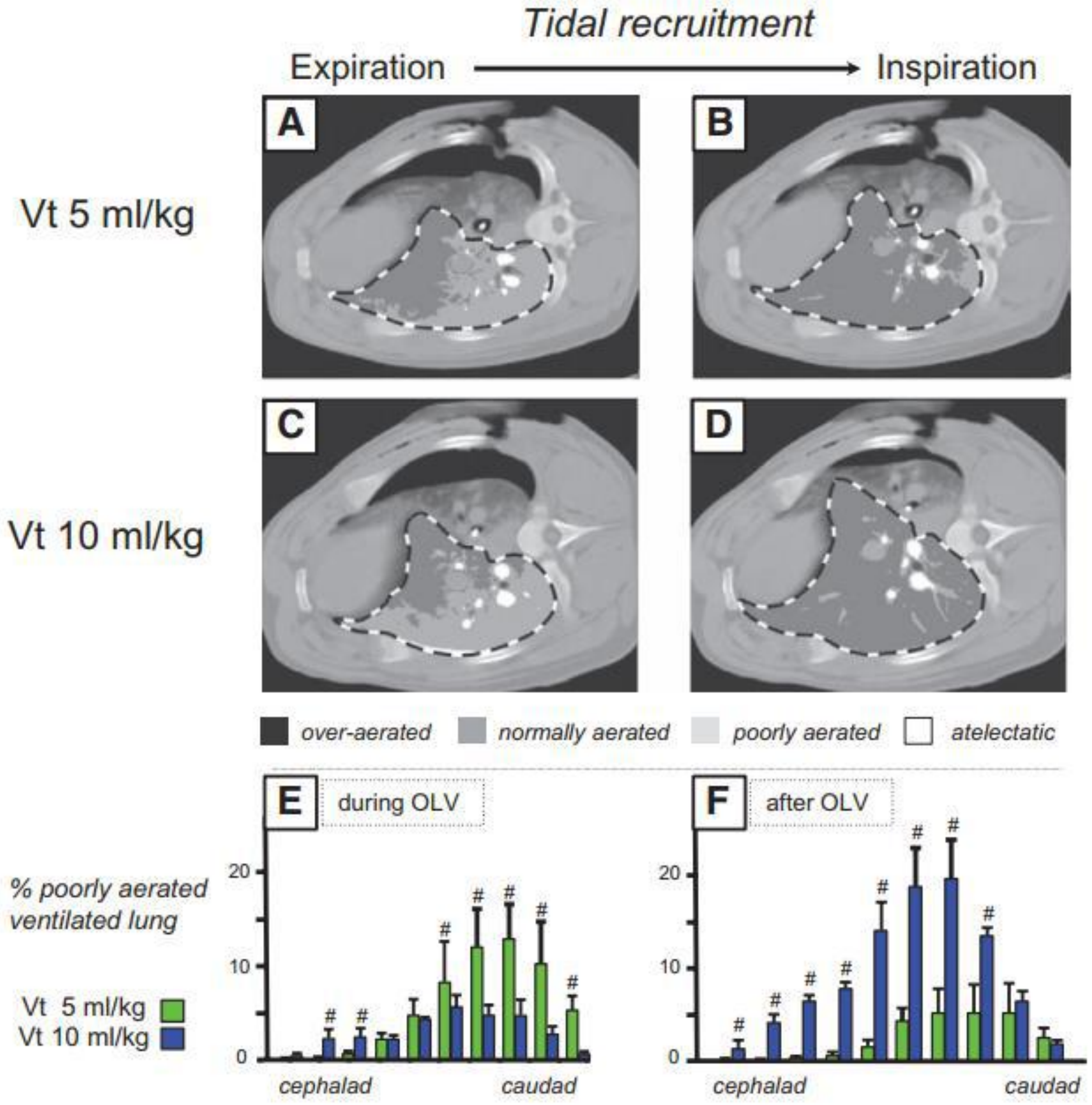
Anesthesia & Analgesia 121(2):p 302-318, August 2015. | ***DOI:*** 10.1213/ANE.0000000000000808



Bx = lung biopsy; Lobe = lobectomy; 2-lobe = bilobectomy;
MDA = malondialdehyde; Pneum = pneumonectomy.

PLV implication in OLV

OLV in pig-model:
more tidal recruitment during OLV,
resulting in increased amounts of poorly aerated lung tissue
on resumption of 2-lung ventilation
(#P < 0.05; Vt 5 vs 10 mL/kg).



Kozian A, Schilling T, Schütze H, Senturk M, Hachenberg T, Hedenstierna G. Ventilatory protective strategies during thoracic surgery: effects of alveolar recruitment maneuver and low-tidal volume ventilation on lung density distribution. Anesthesiology 2011;114:1025–35

Intraoperative- Protective Lung Ventilation

BIOMEDICAL REPORTS 20: 73, 2024

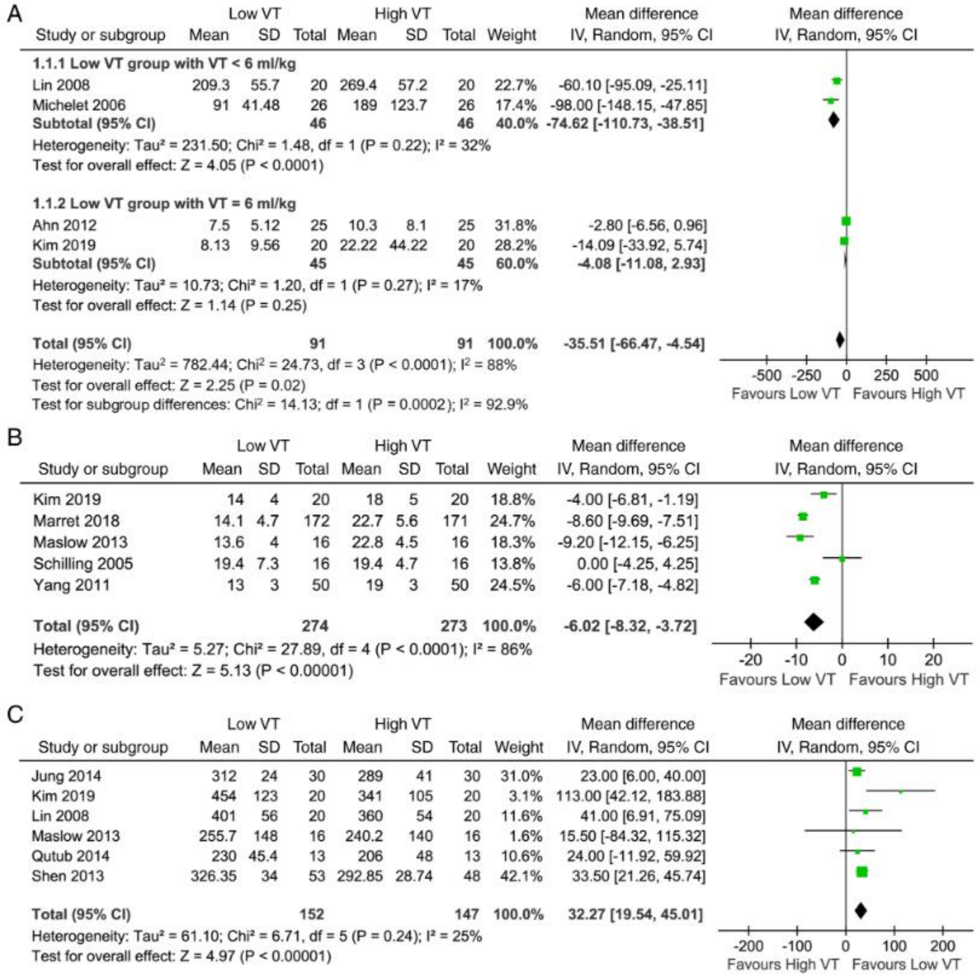
Effects of tidal volume on physiology and clinical outcomes in patients with one-lung ventilation undergoing surgery: A meta-analysis of randomized controlled trials

JIE JIANG[1,2], FEIPING XIA[1], ZHONGHUA LU[1], YUYING TANG[1], HAIBO QIU[3], YI YANG[3] and FENGMEI GUO[3]

[1]Department of Critical Care Medicine, School of Medicine, Southeast University, Nanjing, Jiangsu 210009; [2]Department of Critical Care Medicine, Nanjing Central Hospital, Nanjing, Jiangsu 210018; [3]Jiangsu Provincial Key Laboratory of Critical Care Medicine, Department of Critical Care Medicine, Zhongda Hospital, School of Medicine, Southeast University, Nanjing, Jiangsu 210009, P.R. China

Received May 8, 2023; Accepted February 16, 2024

DOI: 10.3892/br.2024.1761

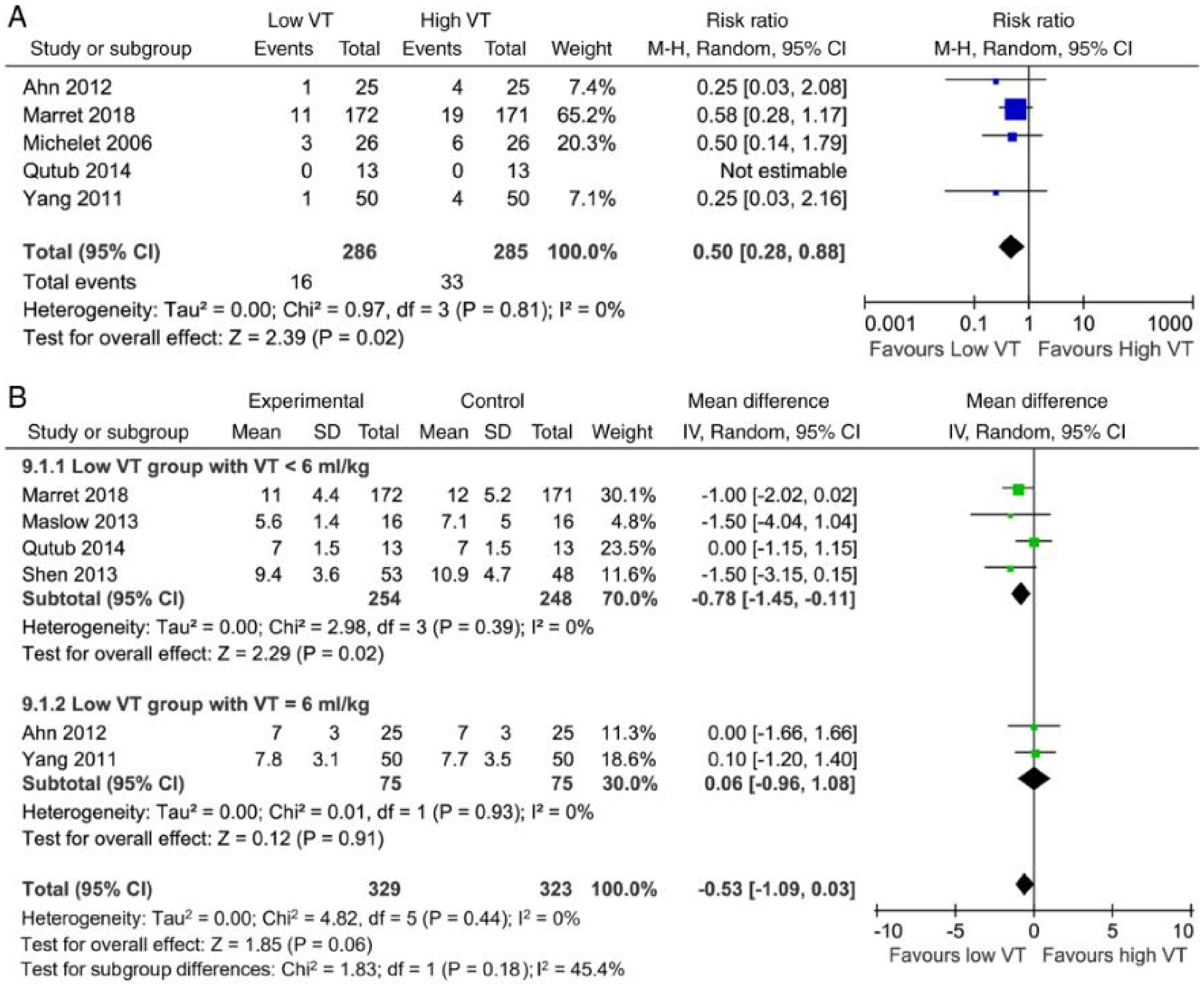


A: Il-6 B: driving pressure C: P/F ratio

Intraoperative- Protective Lung Ventilation

Favor outcomes of:
reduced risk of ALI, Il-6 secretion, driving pressure, P/F oxygen

But not length of hospital stay



A: risk of ALI B: length of hospital stay

Lung Isolation

ANESTHESIOLOGY

Hypoxemia in Young Children Undergoing One-lung Ventilation: A Retrospective Cohort Study

T. Wesley Templeton, M.D., Scott A. Miller, M.D., Lisa K. Lee, M.D., M.S., Sachin Kheterpal, M.D., M.B.A., Michael R. Mathis, M.D., Eduardo J. Goenaga-Díaz, M.D., Leah B. Templeton, M.D., Amit K. Saha, Ph.D.; for the Multicenter Perioperative Outcomes Group Investigators*

Anesthesiology 2021; 135:842–53

ABSTRACT

Background: One-lung ventilation in children remains a specialized practice with low case numbers even at tertiary centers, preventing an assessment of best practices. The authors hypothesized that certain case factors may be associated with a higher risk of intraprocedural hypoxemia in children undergoing thoracic surgery and one-lung ventilation.

Methods: The Multicenter Perioperative Outcomes database and a local quality improvement database were queried for documentation of one-lung ventilation in children 2 months to 3 yr of age inclusive between 2010 and 2020. Patients undergoing vascular or other cardiac procedures were excluded. All records were reviewed electronically for the presence of hypoxemia, oxygen saturation measured by pulse oximetry (Spo_2) less than 90% for 3 min or more continuously, and severe hypoxemia, Spo_2 less than 90% for 5 min or more continuously during one-lung ventilation. Records were also assessed for hypercarbia, end-tidal CO_2 greater than 60 mmHg for 5 min or more or a $Paco_2$ greater than 60 on arterial blood gas. Covariates assessed for association with these outcomes included age, weight, American Society of Anesthesiologists (Schaumburg, Illinois) Physical Status 3 or greater, duration of one-lung ventilation, preoperative Spo_2 less than 98%, bronchial blocker *versus* endobronchial intubation, left operative side, video-assisted thoracoscopic surgery, lower tidal volume ventilation (tidal volume less than or equal to 6 ml/kg plus positive end expiratory pressure greater than or equal to 4 cm H_2O for more than 80% of the duration of one-lung ventilation), and type of procedure.

Results: Three hundred six cases from 15 institutions were included for analysis. Hypoxemia and severe hypoxemia occurred in 81 of 306 (26%) patients and 56 of 306 (18%), respectively. Hypercarbia occurred in 153 of 306 (50%). Factors associated with lower risk of hypoxemia in multivariable analysis included left operative side (odds ratio, 0.45 [95% CI, 0.251 to 0.78]) and bronchial blocker use (odds ratio, 0.351 [95% CI, 0.177 to 0.67]). Additionally, use of a bronchial blocker was associated with a reduced risk of severe hypoxemia (odds ratio, 0.290 [95% CI, 0.125 to 0.62]).

Conclusions: Use of a bronchial blocker was associated with a lower risk of hypoxemia in young children undergoing one-lung ventilation.

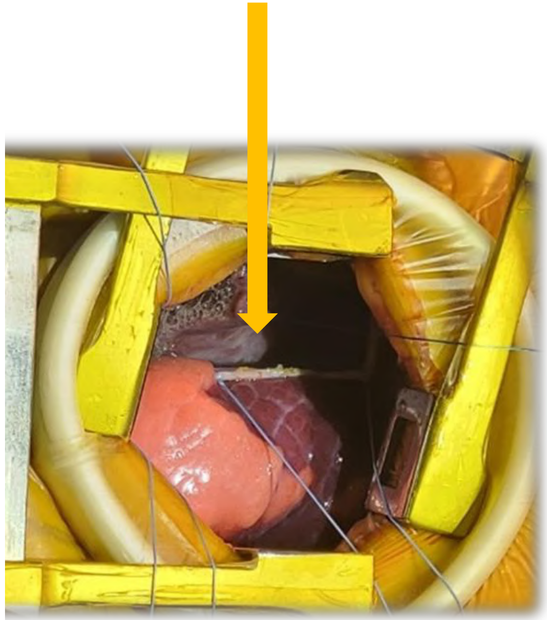
Lung Isolation

Overview of OLV

Table 2. Summary of Strategies for OLV in Infants and Young Children

Strategy for OLV	Appropriate Age	Advantages	Disadvantages
Endobronchial intubation	<5 y	• Easy to perform • No special blocker or tube required • Can be performed blindly, with fiberoptic assistance or under fluoroscopy • Good quality isolation	• Difficult to change to two-lung ventilation • ETT can become occluded with blood and/or secretions • Easy to occlude right upper lobe bronchus with right-sided endobronchial intubation
Bronchial blocker	All age groups	• Technique of choice in young children with a difficult airway • High quality of isolation • Rapidly change from OLV to two-lung ventilation • Appropriate for all ages depending on size and type of blocker • Intra or extraluminal use • Appropriate for children with a tracheostomy • Can be used in combination with a supraglottic airway	• Inability to suction nonventilated lung or apply CPAP • Can be technically challenging to position • CPAP to nonventilated lung may be ineffective • Can be easily dislodged as a result of surgical manipulation
Univent tube	>8 y	• High quality of isolation • May be more positionally stable than a bronchial blocker • Easy to change from OLV to two-lung ventilation	• Appropriate for children ≥8 y of age • Smaller ventilating lumen relative to patient size may lead to increased resistance
Double lumen tube	>8 y	• Usually straight forward to position • High quality of isolation • Positionally stable • Easy to change from OLV to two-lung ventilation • Can suction and apply CPAP to nonventilated lung	• Appropriate for children ≥8 y of age • Potentially increased rates of glottic or tracheal injury • Not appropriate in most children with a difficult airway

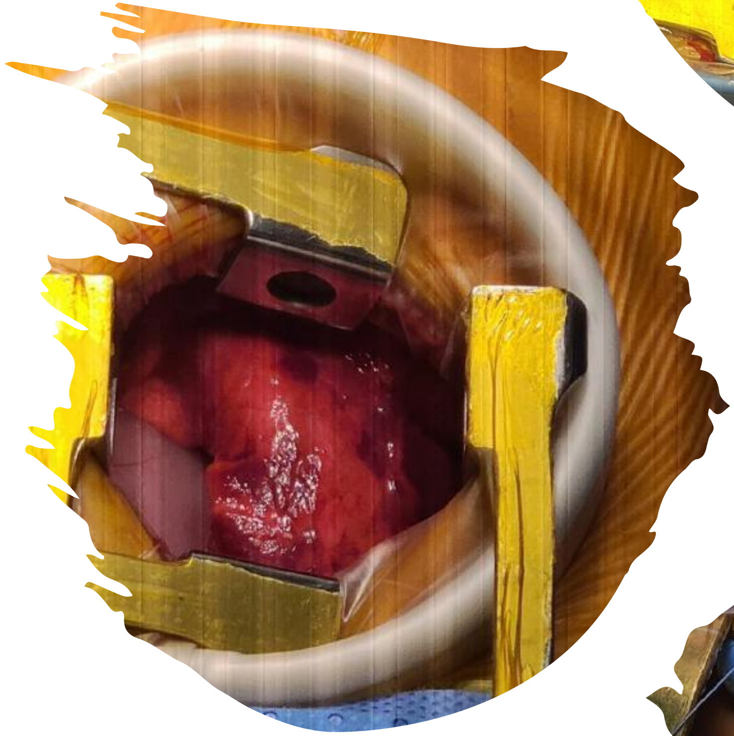
See Supplemental Digital Content, Table 1, http://links.lww.com/AA/D159, for the indications for OLV in children.
Abbreviations: CPAP, continuous positive airway pressure; ETT, endotracheal tube; OLV, one-lung ventilation.



An Update on one lung ventilation in children-*Anesthesia & Analgesia* 132(5):p 1389-1399, May 2021. Templeton, T. Wesley MD*; Piccioni, Federico MD†; Chatterjee, Debnath MD, FAAP‡

Surgical manipulation

- But it’s the unavoided things!
- Just sure to be aware of this & MIS



PLV implication in OLV

Mechanisms of lung injury	Evidence	Author's suggestions
Surgical trauma	Lung injury to the operated lung is proportional to the surgical aggression	Consider minimally invasive and video-assisted surgery whenever possible
Ischemia–reperfusion (I–R) Oxidative stress	Lung injury to the operated lung caused by I–R and oxidative stress are well-known problems during and after OLV	Decrease OLV time; use the lowest FiO_2 possible; re-expand the operated lung with a low FiO_2
Fast lung re-expansion after OLV	Abrupt and fast re-expansion of the operated lung with high driving pressures and volumes increases the stress in lung tissue	Re-expand the operated lung with a ventilator instead of a bag using a controlled cyclic step-wise and slow recruitment maneuver similar to the alveolar recruitment strategy
Local hypoxia by atelectasis	A mild inflammatory response develops locally in collapsed areas of the lungs	Decrease OLV time Treat lung collapse in the ventilated lung by a recruitment maneuver
Positive fluid balance	Excess of intravascular fluid is an independent risk factor for ARDS in patients undergoing thoracic surgeries	Apply goal-directed fluid therapy keeping normal cardiac output and oxygen delivered at the lowest amount of i.v fluids possible Low doses of vasoactive drugs help maintain a neutral fluid balance in case of vasodilation Consider inhaled B2 agents to decrease pulmonary edema Consider hydrocortisone to preserve the endothelial glycocalix
Capillary stress failure	Hyperperfusion of lung tissue caused by OLV, vascular clamping and declamping, and excess of inotropic vasoactive drugs injures the alveolar-capillary membrane	Perform vascular clamping and declamping slowly and avoid high doses of inotropic and vasoactive drugs
VILI	Tidal recruitment and overdistension is the main causes of VILI	Apply a goal-directed ventilatory strategy that consists of an active recruitment maneuver and sufficiently high PEEP (10 ± 2 cm H_2O) to keep the lungs open Ventilate the open lung with a protective pattern at very low VTs (4 mL/kg) and low plateau pressures

Tusman G, Bohm SH, Suarez-Sipmann F. Alveolar Recruitment Maneuvers for One-Lung Ventilation During Thoracic Anesthesia. *Curr Anesthesiol Rep*.2014;4(2):160-169

PLV & ARM

03

Contraindications for RMs:
- hemodynamic instability
- COPD and lung emphysema
- bronchopleural fistula
- acute cor pulmonale.

Relative contraindications: ↗ ICP

ARM in Lung isolation

- When?
- How to do?
- How to evaluate it's efficacy

Comparative Study > Crit Care Med. 2011 May;39(5):1074-81.
doi: 10.1097/CCM.0b013e318206d69a.

Impact
recruit
bioche

Pedro L Silva
Tatiana Marc
John J Marin

Affiliations
PMID: 21263

> Minerva Anestesiol. 2013 Jun;79(6):590-603. Epub 2013 Feb 28.

The immune response to one-lung-ventilation is not affected by repeated alveolar recruitment ma

T Schil

Affiliat
PMID:

> Anesthesiology. 2011 May;114(5):1025-35. doi: 10.1097/ALN.0b013e3182164356.

Ventilatory protective strategies during thoracic surgery: effects of alveolar recruitment maneuver and low-tidal volume ventilation on lung density distribution

Alf Kozian [1], Thomas Schilling, Hartmut Schütze, Mert Senturk, Thomas Hachenberg, Göran Hedenstierna

Affiliations + expand
PMID: 21436678 DOI: 10.1097/ALN.0b013e3182164356

ARM in Lung isolation

- When?
  - After intubation
  - ? Not right before OLV: risk of ↓ quality of collapsed lung
  - Lung recruitment and PEEP titration should be repeated in case of deteriorating oxygenation, but not routinely

ARM in Lung isolation

- How to do?
  - Stepwise increasing PEEP
  - Use programmed ARM in anesthesia machine
  - Prolonged RM can benefit the lung

ARM in Lung isolation

- How to do?

Intensive Care Med (2011) 37:1572–1574
DOI 10.1007/s00134-011-2329-7

EDITORIAL

John J. Marini

Recruitment by sustained inflation: time for a change

Marini, J.J. Recruitment by sustained inflation: time for a change. *Intensive Care Med* **37**, 1572–1574 (2011). https://doi.org/10.1007/s00134-011-2329-7

Figure 1: Setting of a sustained inflation RM using the P/V Tool

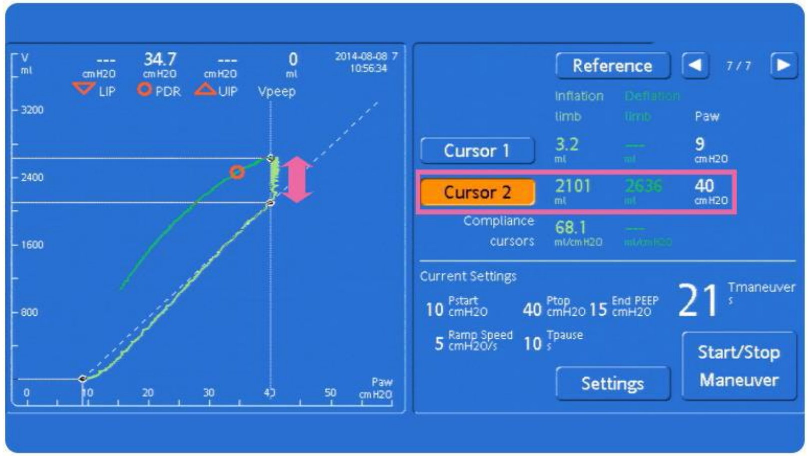


Figure 2: The volume increase during the pause represents the volume of lung that was reaerated

P/V Tool® Pro on Hamilton Medical ventilators

ARM- PEEP

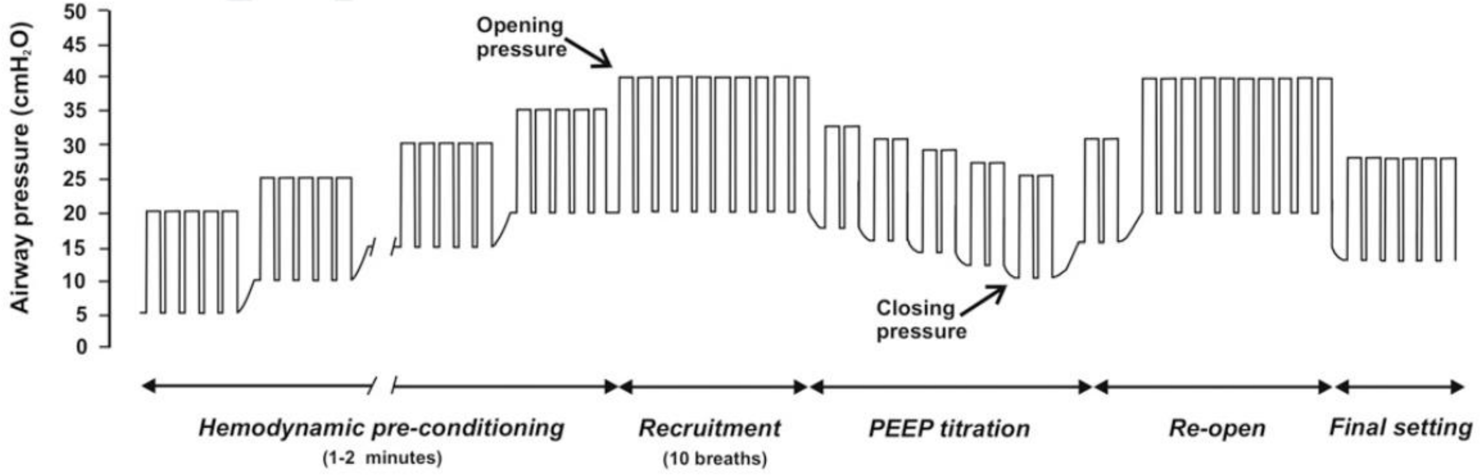
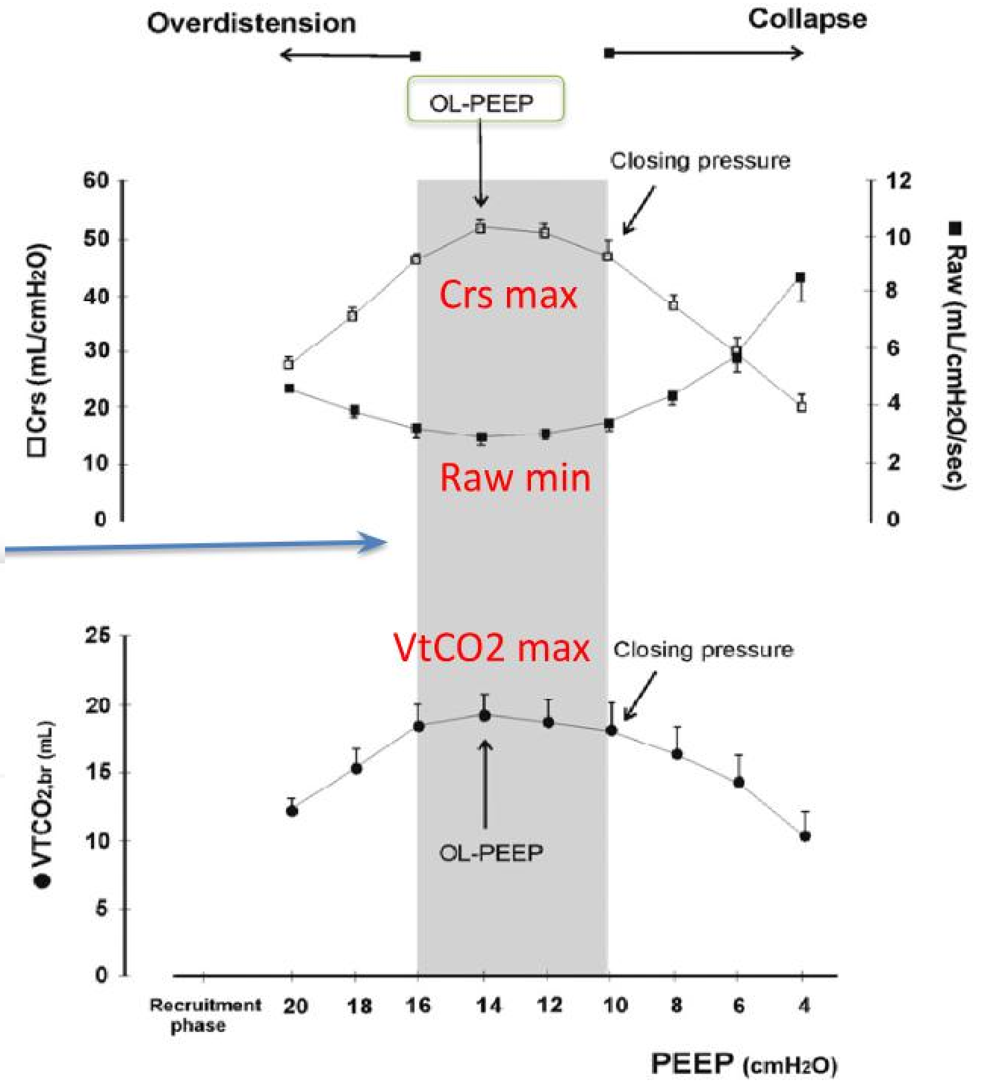


Fig. 1. Scheme of the alveolar recruitment strategy. The ARS is performed in pressure cont represents a tidal volume. PEEP is increased in steps of 5 cm H2O during the hemodynamic p reach the opening pressure of the lungs. After 10 breaths a complete open lung state is ach reducing PEEP in steps of 2 cm H2O, from 20 cm H2O until the closing pressure is found. Late a protective setting (low VT) but at the established OL-PEEP. Collapse



Published in 2010

Treatment of anesthesia-induced lung collapse with lung recruitment maneuvers

G. Tusman J. Belda

PLV & ARM

How to evaluate it's efficacy:

- Maximum volume change from end-expiratory
- Elastance: decrease (if over-distention ΔEl positive)
- Trans-pulm pressure: peak, mean
- Maybe have role of Lung Ultrasound

My key points:

- Use Bronchial Blocker for lung isolation in children
- PLV while one lung ventilation, manage to reduce duration of OLV
- Tailoring ARM & PLV for individual patient

Thank you for listening!