Université Lille Nord de France
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Ventilation protectrice ?

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FACULTE DE MEDECINE HENRI WAREMBOURG

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VOLUME 342 MAY 4, 2000 NUMBER 18

VENTILATION WITH LOWER TIDAL VOLUMES AS COMPARED WITH TRADITIONAL TIDAL VOLUMES FOR ACUTE LUNG INJURY AND THE ACUTE RESPIRATORY DISTRESS SYNDROME

THE ACUTE RESPIRATORY DISTRESS SYNDROME NETWORK*

TABLE 1. SUMMARY OF VENTILATOR PROCEDURES.*

VARIABLE	GROUP RECEIVING TRADITIONAL TIDAL VOLUMES	GROUP RECEIVING LOWER TIDAL VOLUMES
Ventilator mode	Volume assist–control	Volume assist–control
Initial tidal volume (ml/kg of predicted body weight)†	12	6
Plateau pressure (cm of water)	≤50	≤30
Ventilator rate setting needed to achieve a pH goal of 7.3 to 7.45 (breaths/min)	6–35	6–35
Ratio of the duration of inspiration to the duration of expiration	1:1–1:3	1:1–1:3

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THE ACUTE RESPIRATORY DISTRESS SYNDROME NETWORK*

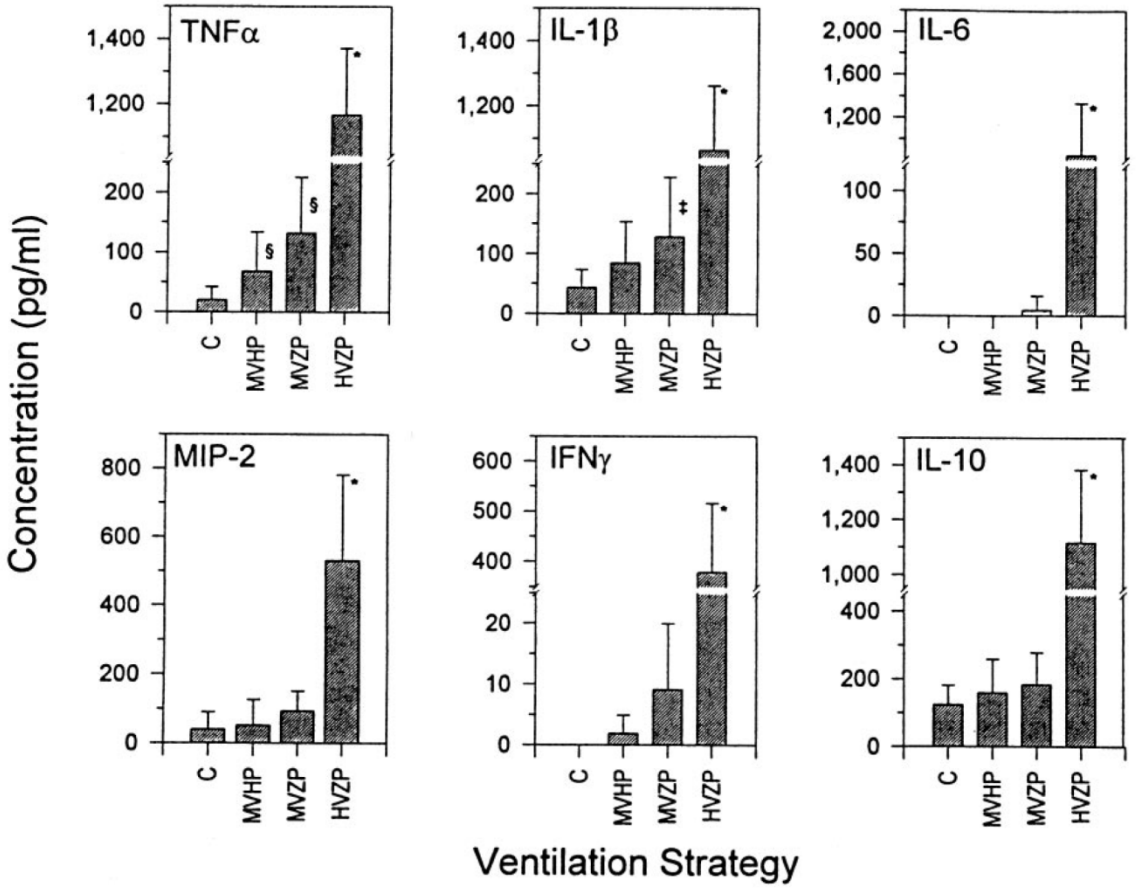
TABLE 4. MAIN OUTCOME VARIABLES.*

VARIABLE	GROUP RECEIVING LOWER TIDAL VOLUMES	GROUP RECEIVING TRADITIONAL TIDAL VOLUMES	P VALUE
Death before discharge home and breathing without assistance (%)	31.0	39.8	0.007
Breathing without assistance by day 28 (%)	65.7	55.0	<0.001
No. of ventilator-free days, days 1 to 28	12±11	10±11	0.007
Barotrauma, days 1 to 28 (%)	10	11	0.43
No. of days without failure of nonpulmonary organs or systems, days 1 to 28	15±11	12±11	0.006

Ventilator-induced Lung Injury

Lessons from Experimental Studies

DIDIER DREYFUSS and GEORGES SAUMON



C : contrôle

MV-HP : Vt modéré, PEEP haute

MV-ZP : Vt modéré, PEEP = 0

HV-ZP : Vt élevé, PEEP = 0

Am J Respir Crit Care Med Vol 157. pp 294–323, 1998

Effect of Mechanical Ventilation on Inflammatory Mediators in Patients With Acute Respiratory Distress Syndrome

A Randomized Controlled Trial

V. Marco Ranieri, MD
Peter M. Suter, MD
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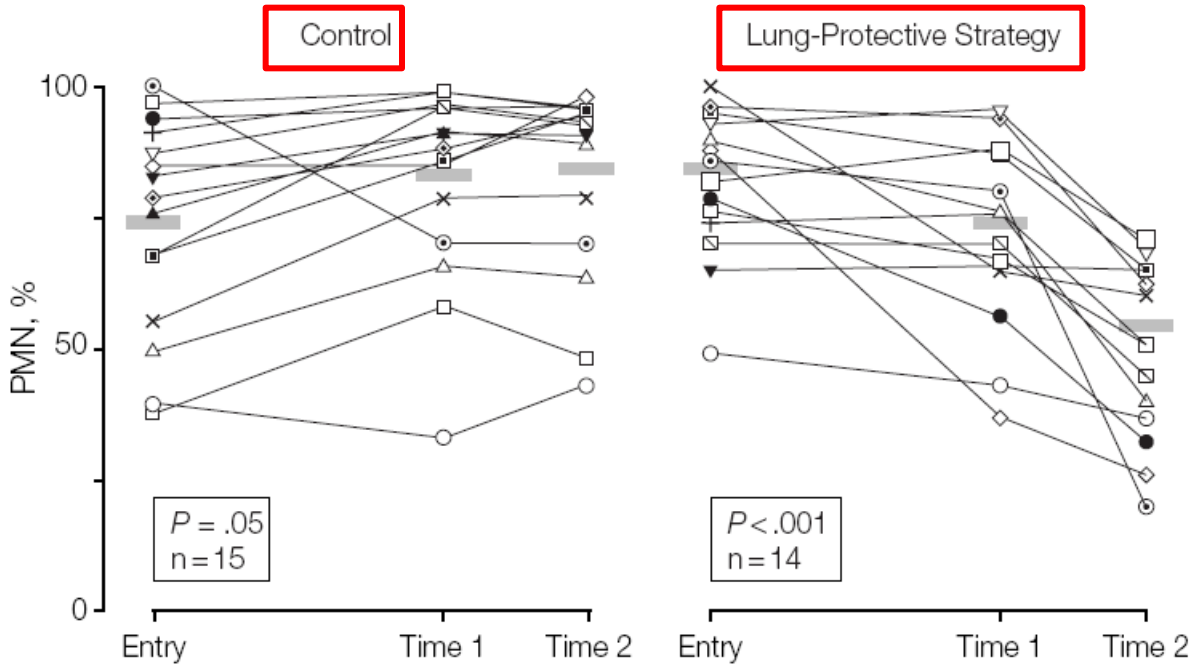

Concentration en PN (LBA)

JAMA. 1999;282:54-61

Effect of Mechanical Ventilation on Inflammatory Mediators in Patients With Acute Respiratory Distress Syndrome

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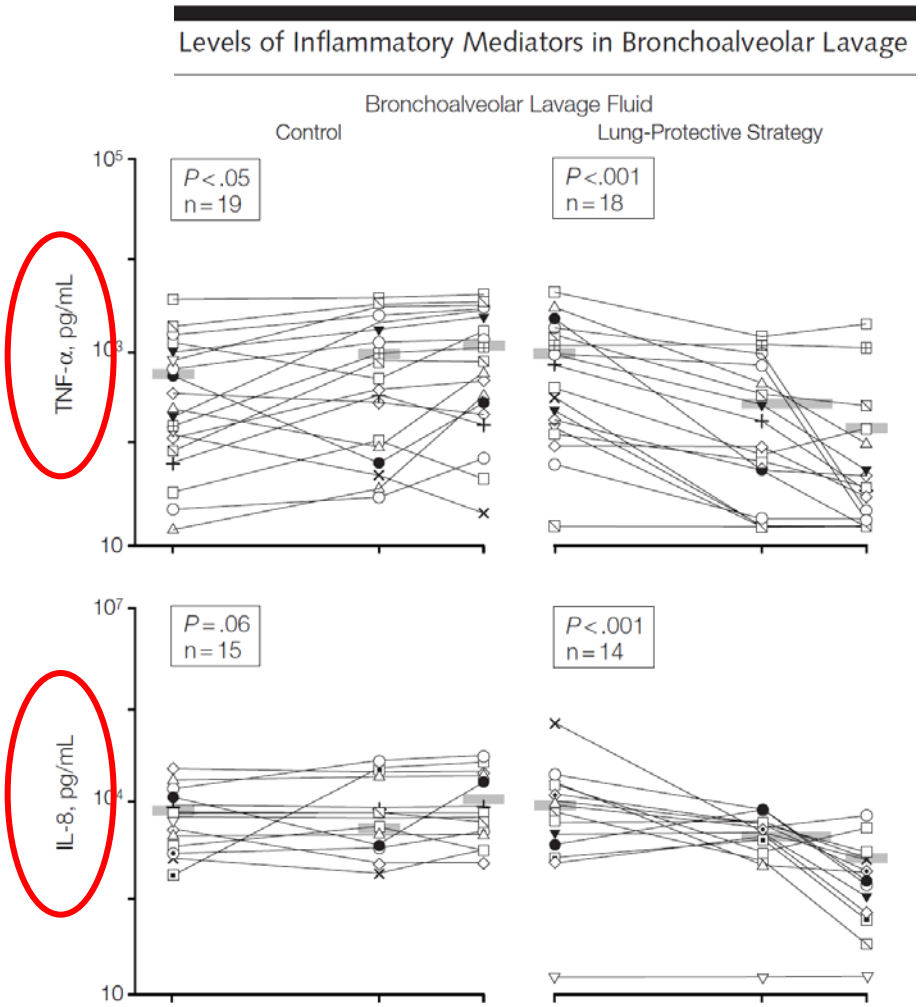


JAMA. 1999;282:54-61

Déductions et Questions

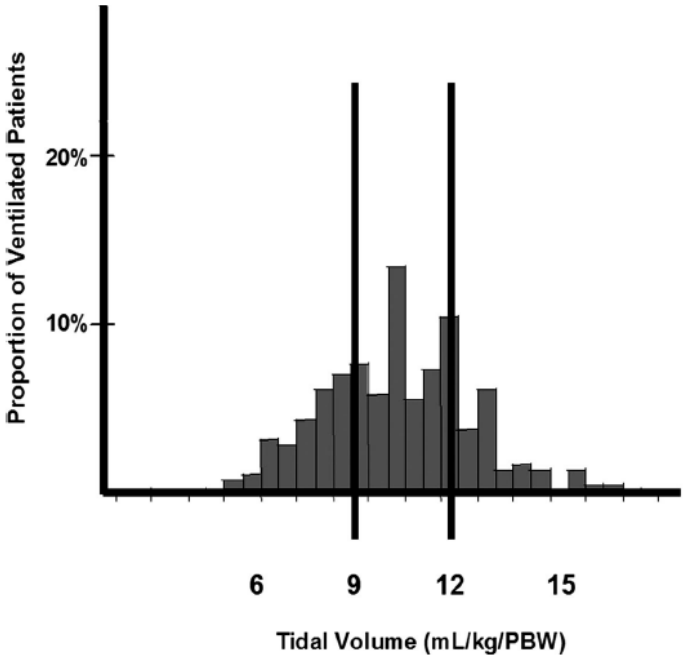
- « VILI » : lésions pulmonaires induites par la ventilation
- Rôle ++ du volume courant
- Ventilation « protectrice » dans le SDRA

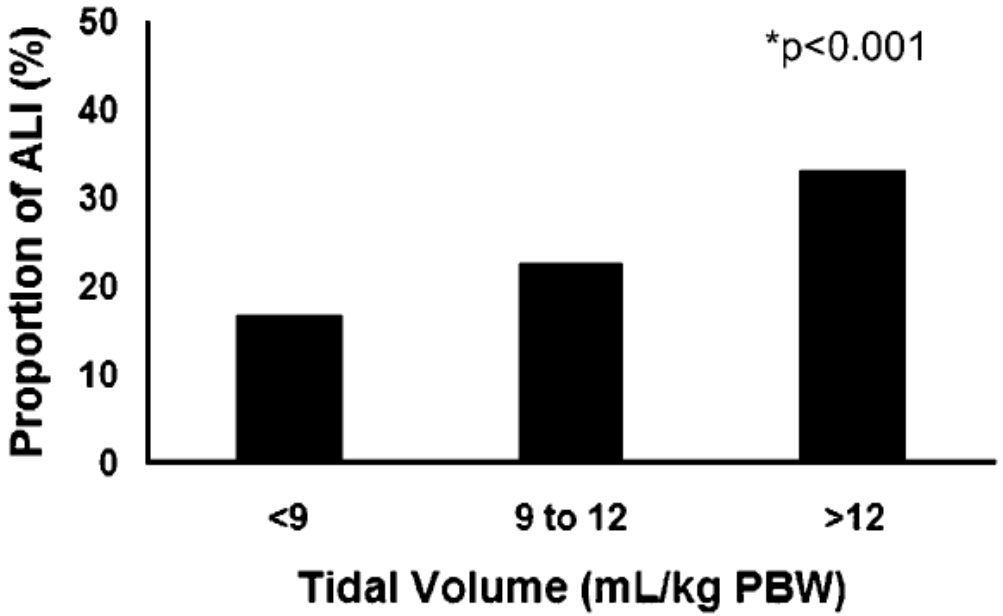
- Poids idéal théorique
  - Hommes : T-100-[(T-150)/4]
  - Femmes : T-100-[(T-150)/2.5]

- VILI / « ventilation protectrice »
  - au cours de la ventilation prolongée (SI-Réa) ?
  - au bloc opératoire (patients à risque?)
  - au bloc opératoire en routine ?

Ventilator-associated lung injury in patients without acute lung injury at the onset of mechanical ventilation*

Ognjen Gajic, MD; Saqib I. Dara, MD; Jose L. Mendez, MD; Adebola O. Adesanya, MD; Emir Festic, MD; Sean M. Caples, MD; Rimki Rana, MD; Jennifer L. St. Sauver, PhD; James F. Lymp, PhD; Bekele Afessa, MD; Rolf D. Hubmayr, MD





Crit Care Med 2004 Vol. 32, No. 9

Intraoperative Tidal Volume as a Risk Factor for Respiratory Failure after Pneumonectomy

Evans R. Fernández-Pérez, M.D.,* Mark T. Keegan, M.B.M.R.C.P.I.,† Daniel R. Brown, M.D., Ph.D.,† Rolf D. Hubmayr, M.D.,‡ Ognjen Gajic, M.D., M.Sc.§

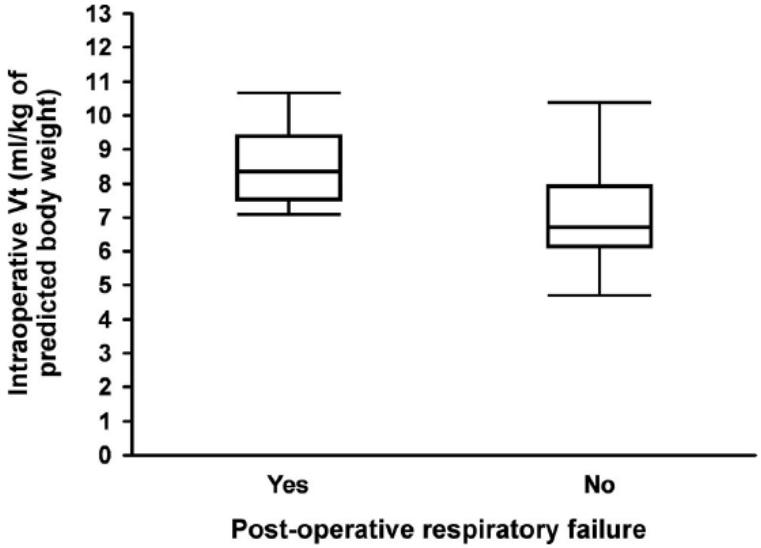


Fig. 1. Median (*horizontal line*), 25th and 75th percentiles (*box*), and range (*whiskers*) of intraoperative tidal volume (V_T) in patients who did and did not develop postpneumonectomy respiratory failure.

Table 2. Risk Factors Associated with Development of Postoperative Respiratory Failure: Multivariate Logistic Regression Analysis

	Odds Ratio	95% CI Lower	95% CI Upper	*P* Value
Intraoperative V_T	1.56*	1.12	2.23	0.009
Preoperative FVC	0.98†	0.96	1.01	0.206
Fluid	1.34‡	0.83	2.09	0.201
Intraoperative $V_T \times$ fluid	1.36§	1.05	1.97	0.005

Anesthesiology 2006; 105:14–8

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Intraoperative ventilator settings and acute lung injury after elective surgery: a nested case control study

E R Fernández-Pérez,[1,6] J Sprung,[3] B Afessa,[2,6] D O Warner,[3] C M Vachon,[4] D R Schroeder,[5] D R Brown,[3] R D Hubmayr,[2,6] O Gajic[2,6]

Table 2 Postoperative pulmonary complications (with and without respiratory failure) by type of surgery

Type of surgery	n	Hydrostatic oedema (n (%))	ALI (n (%))	Pneumonia (n (%))	Atelectasis (n (%))	Pneumothorax (n (%))
Cardiac	1381	147 (10.6)	79 (5.7)	38 (2.7)	11 (0.8)	8 (0.6)
Thoracic	659	14 (2)	24 (3.6)	14 (2)	6 (0.9)	3 (0.4)
Open abdomen	547	7 (1.2)	8 (1.5)	2 (0.4)	1 (0.2)	2 (0.4)
Orthopaedic	399	12 (3)	4 (1)	1 (0.2)	1 (0.2)	1 (0.2)
Peripheral vascular	352	4 (1)	2 (0.6)	1 (0.3)	0	0
Neurological	339	2 (0.6)	3 (0.9)	2 (0.6)	0	0
Non-orthopaedic spine	258	2 (0.8)	0	0	1	0
Aortic vascular	148	23 (15)	11 (7.4)	6 (4)	0	0
Laparoscopic abdominal	123	2 (1.6)	1 (0.8)	1 (0.8)	1 (0.8)	0
Urological	158	3 (1.8)	0	0	0	0
Head and neck	24	1 (4)	1 (4)	2 (8)	0	0
General	33	0	0	0	0	0
Total (%)	4420	217 (4.9)	133 (3)	67 (1.5)	21 (0.5)	14 (0.3)

ALI, acute lung injury.

Thorax 2009;**64**:121–127

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Table 6 Unadjusted univariate and adjusted multivariate analysis of intraoperative ventilator variables of matched ALI case controls

Variable	Controls (n = 166) (mean (SD))	Cases (n = 83) (mean (SD))	Unadjusted OR (95%CI)	p Value	Adjusted OR (95%CI)*	p Value
First hour						
Tidal volume/kg PBW	8.7 (1.7)	8.9 (1.6)	1.08 (0.92–1.27)	0.336	1.03 (0.84–1.26)	0.801
PEEP (cm H_2O)	1.7 (2.2)	1.4 (2.5)	0.94 (0.83–1.07)	0.344	0.89 (0.77–1.04)	0.180
Peak airway pressure (cm H_2O)	19 (4.8)	21 (5.9)	1.10 (1.04–1.15)	<0.001	1.07 (1.02–1.15)	0.045
Respiratory rate (cycles/min)	11 (1.4)	11 (1.3)	1.01 (0.82–1.24)	0.909	1.01 (0.77–1.32)	0.940
Fio_2 (%)	73 (18)	80 (17)	1.03 (1.01–1.04)	0.002	1.00 (0.98–1.03)	0.708

*Adjusted for diabetes, chronic obstructive pulmonary disease, duration of anaesthesia, total red blood cell given, mean arterial blood pressure, smoking status and alcohol use.
ALI, acute lung injury; Fio_2, fraction of inspired oxygen; PBW, predicted body weight; PEEP, positive end expiratory pressure.

The Effects of Different Ventilatory Settings on Pulmonary and Systemic Inflammatory Responses During Major Surgery

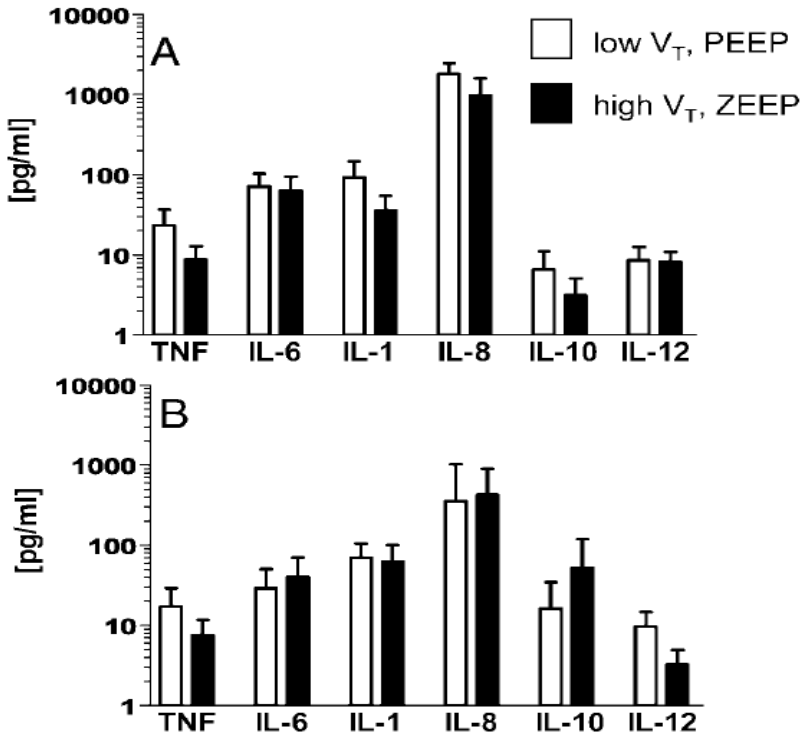
Hermann Wrigge, MD*, Ulrike Uhlig, MSc, PhD†, Jörg Zinserling, MSc*,
Elisabeth Behrends-Callsen*, Gunther Ottersbach*, Matthias Fischer, MD, PhD*,
Stefan Uhlig, MSc, PhD†, and Christian Putensen, MD, PhD*

Chirurgie programmée, durée < 3h

12-15 ml/kg (PEP=0) vs. 6 ml/kg (PEP=10)

Chir abdo

Chir tho



Réponse inflammatoire "locale"

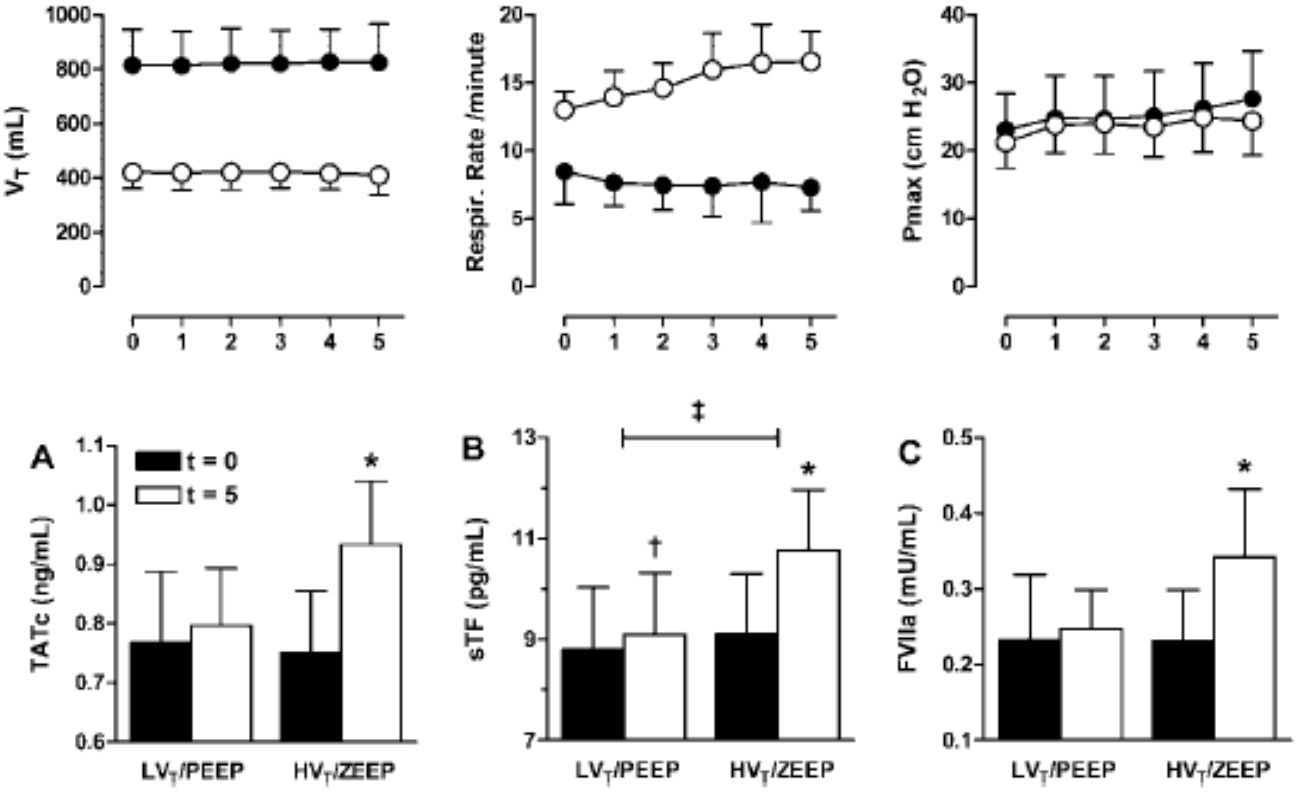
Anesth Analg 2004;98:775–81

Mechanical Ventilation with Lower Tidal Volumes and Positive End-expiratory Pressure Prevents Alveolar Coagulation in Patients without Lung Injury

Goda Choi, M.D.,* Esther K. Wolthuis, M.D.,† Paul Bresser, M.D., Ph.D.,‡ Marcel Levi, M.D., Ph.D.,§
Tom van der Poll, M.D., Ph.D.,|| Misa Dzoljic, M.D., Ph.D.,# Margreeth B. Vroom, M.D., Ph.D.,**
Marcus J. Schultz, M.D., Ph.D.††

Chirurgie programmée, durée > 5h

12 ml/kg (PEP=0) vs. 6 ml/kg (PEP=10)



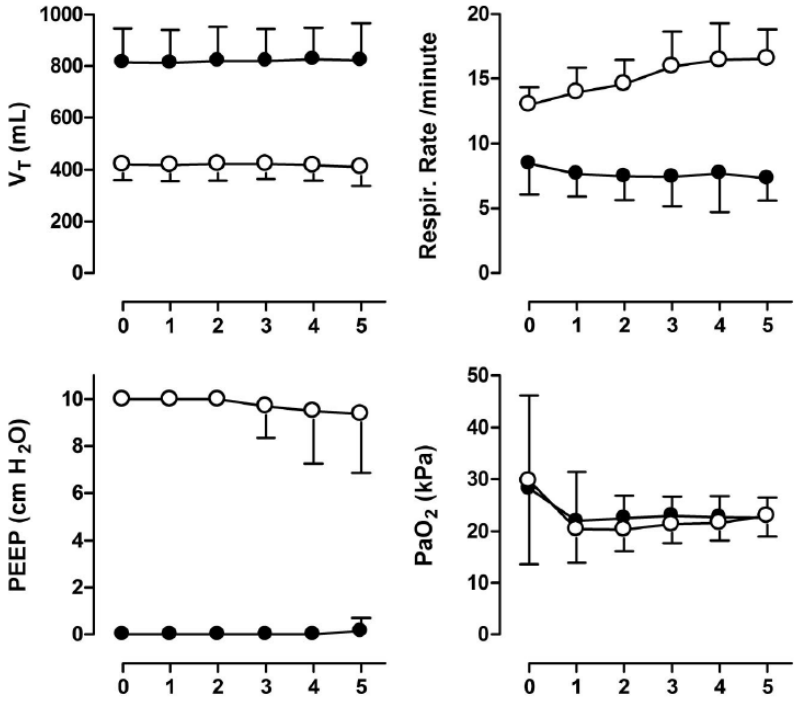
Anesthesiology 2006; 105:689–95

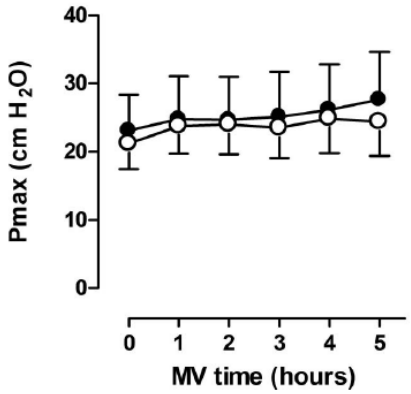
Mechanical Ventilation with Lower Tidal Volumes and Positive End-expiratory Pressure Prevents Pulmonary Inflammation in Patients without Preexisting Lung Injury

Esther K. Wolthuis, M.D., Goda Choi, M.D., Ph.D.,† Mark C. Dessing, Ph.D.,‡ Paul Bresser, M.D., Ph.D.,§ Rene Lutter, Ph.D.,‖ Misa Dzoljic, M.D., Ph.D.,# Tom van der Poll, M.D., Ph.D.,** Margreeth B. Vroom, M.D., Ph.D.,†† Markus Hollmann, M.D., Ph.D.,‡‡ Marcus J. Schultz, M.D., Ph.D.§§*

Chirurgie programmée, durée > 5h

12 ml/kg (PEP=0) vs. 6 ml/kg (PEP=10)





Anesthesiology 2008; 108:46–54

Mechanical Ventilation with Lower Tidal Volumes and Positive End-expiratory Pressure Prevents Pulmonary Inflammation in Patients without Preexisting Lung Injury

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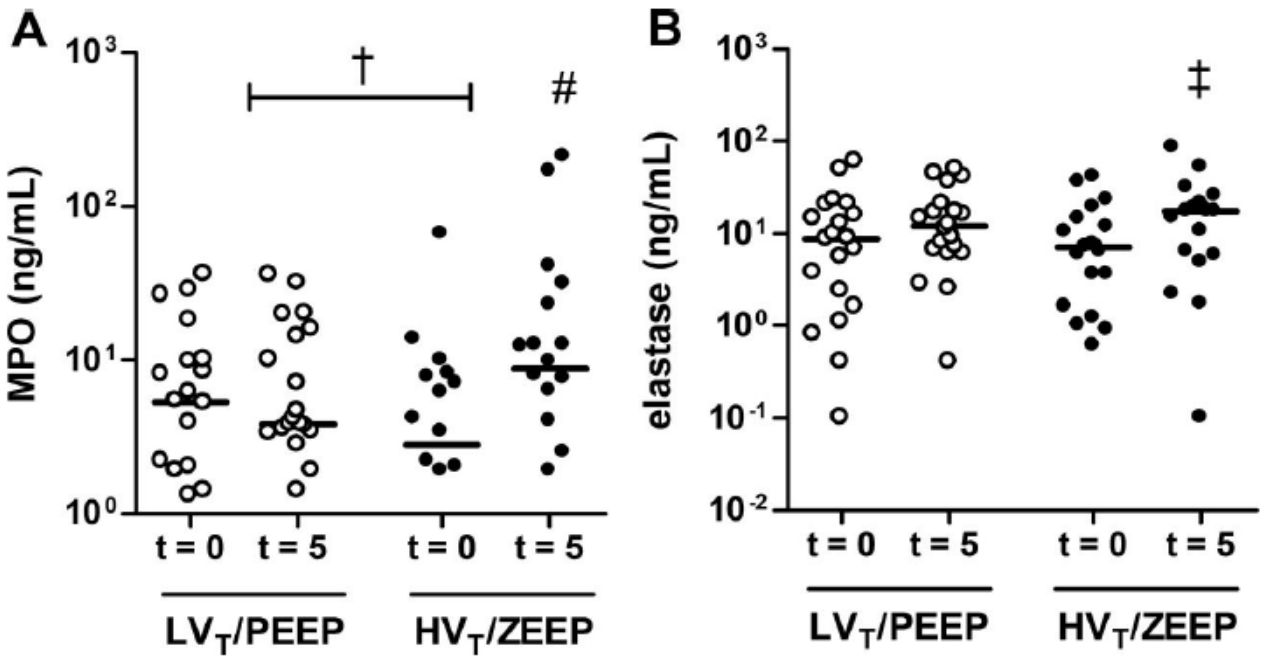
Chirurgie programmée, durée > 5h

12 ml/kg (PEP=0) vs. 6 ml/kg (PEP=10)



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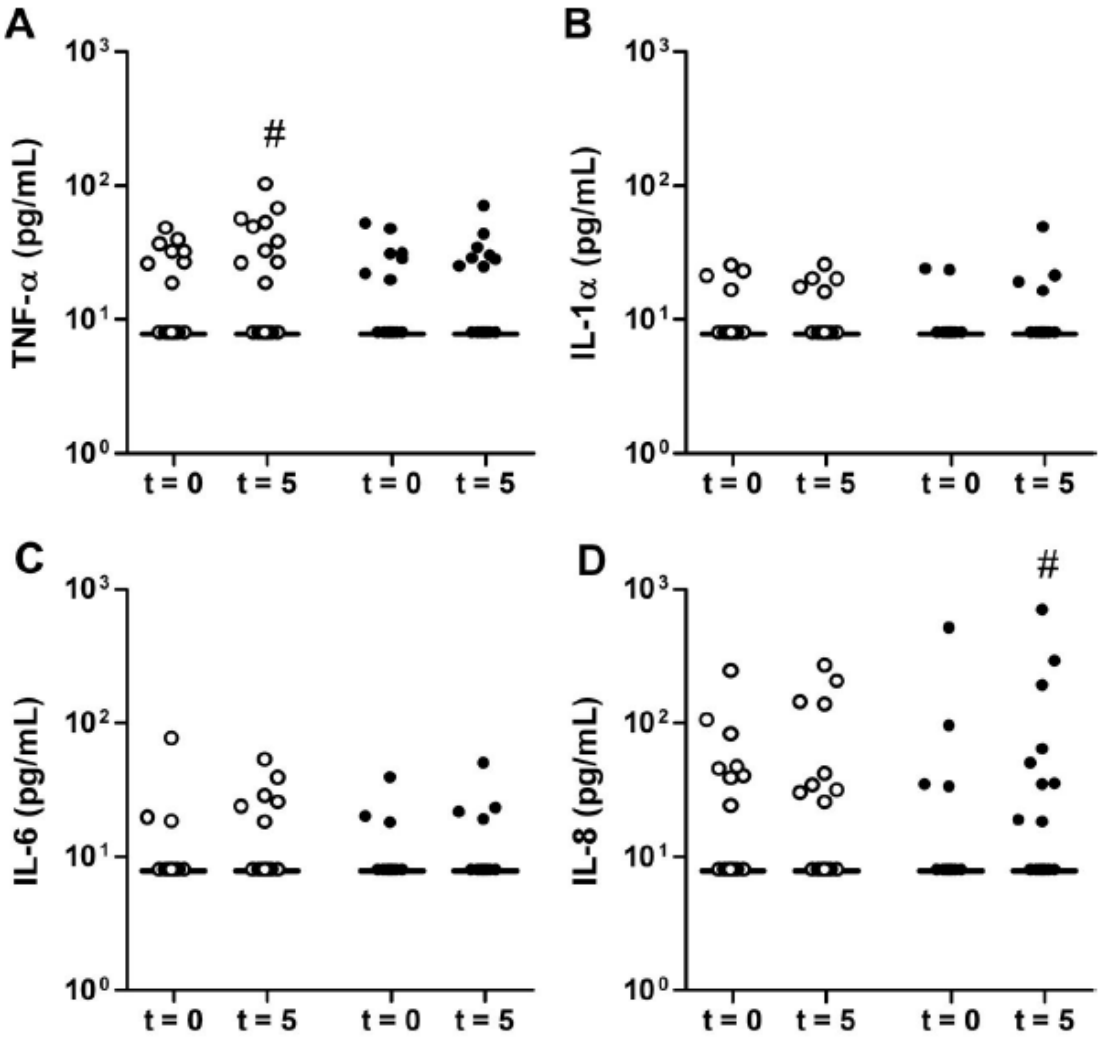


Tidal Volume in Patients With Normal Lungs during General Anesthesia

Lower the Better?

Table 1. Randomized and Controlled Trials Comparing High *versus* Low V_T Ventilation in Cardiac Surgery Patients

Trial	Year	N	Setting*	V_T, ml/kg		Respiratory Rate, l/min		PEEP, cm H_2O		Outcomes for Intervention (Protective Strategy)
				Low	High	Low	High	Low	High	
Chaney MA *et al.*[25]	2000	25	OR	6	12	16	8	5	5	Better lung mechanics, less shunt
Koner O *et al.*[26]	2004	44	OR	6	10	15	9	5	5 or 0	No difference: plasma IL-6, TNF, ventilation time, hospital length of stay
Wrigge H *et al.*[17]	2005	44	ICU	6	12	21	10	9	7	No difference: plasma mediators; lower TNF in broncho-alveolar lavage; subgroup showed faster plasma TNF decline
Zupancich E *et al.*[16]	2005	40	OR	6.8	10.9	12–15	12–15	9.1	2.1	Lower IL-6 and IL-8 in plasma and broncho-alveolar lavage
Reis Miranda D *et al.*[18]	2005	62	OR/ICU	4–6	6–8	NA	NA	14–15	5.5	Faster decline in plasma IL-8 (IL-10)
Sundar S *et al.*[9]	2011	149	OR	6.2	10.0	17	12	5.0	4.9	No difference: ventilation time; fewer patients ventilated 6 h after operation; fewer reintubations

ANESTHESIOLOGY 2011; 114:1102–10

Mechanical ventilation with high tidal volume induces inflammation in patients without lung disease

Critical Care 2010, **14**:R39

Roselaine Pinheiro de Oliveira[1,2], Marcio Pereira Hetzel[1], Mauro dos Anjos Silva[1], Daniele Dallegrave[1], Gilberto Friedman[1,2*]

USI, VC 12h

10-12 ml/kg (PEP=5)

vs.

5-7 ml/kg (PEP=5)

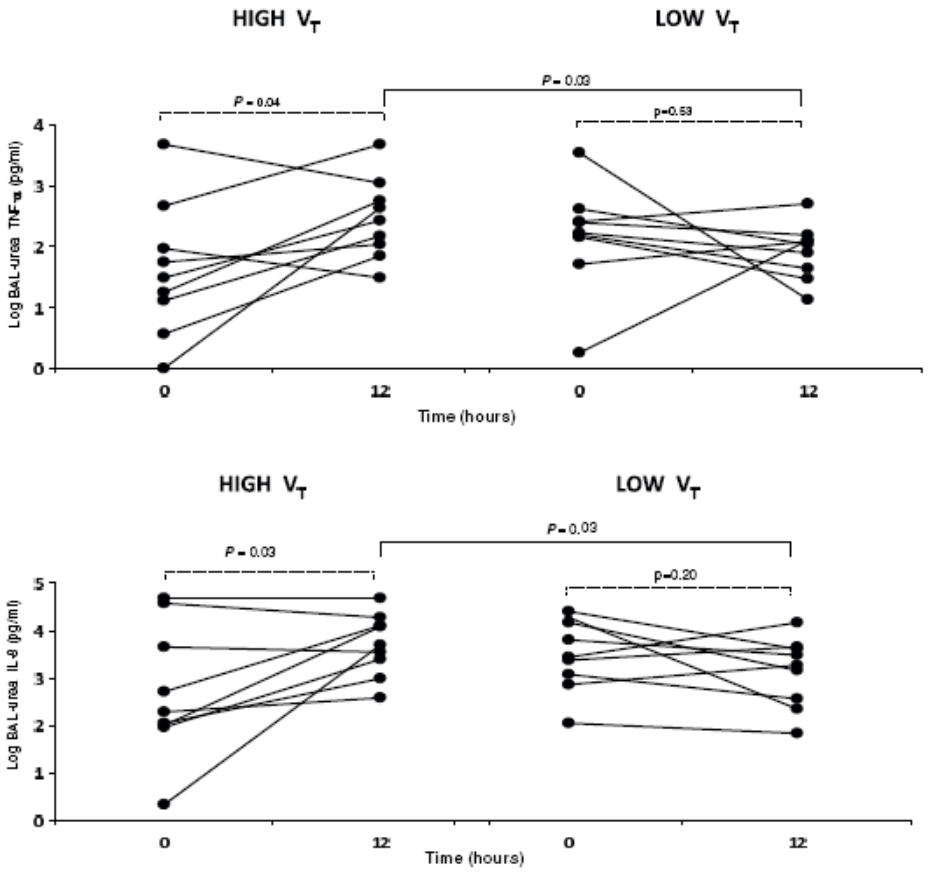


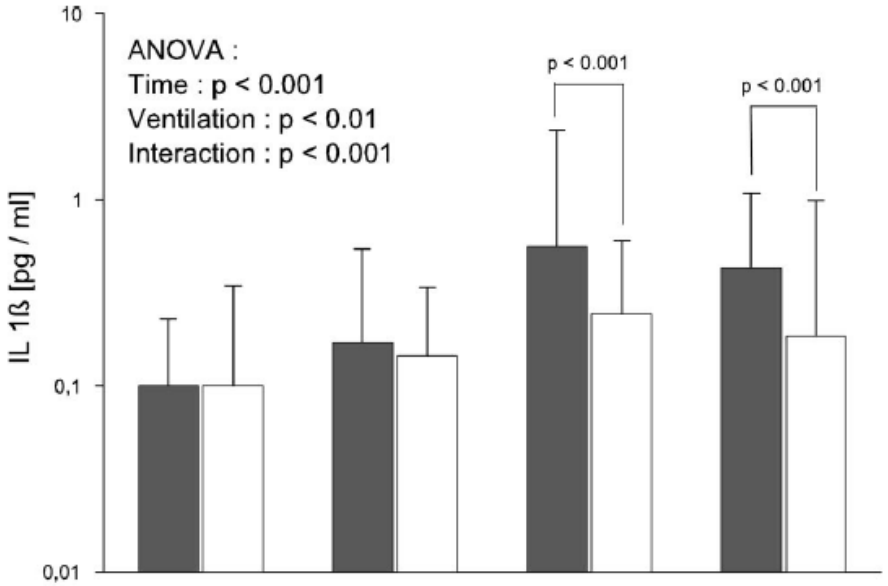
Figure 2 Time course of logarithmic standardized-urea bronchoalveolar lavage (Log BAL-urea) TNF-α (top) and IL-8 (bottom) levels. There were no differences between groups at baseline.

Protective Ventilation Influences Systemic Inflammation after Esophagectomy

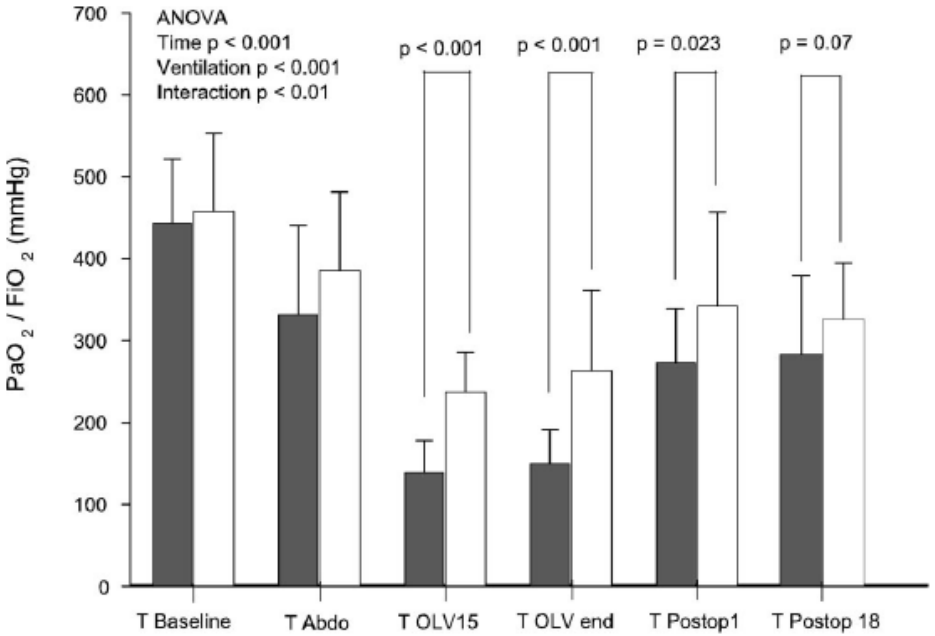
A Randomized Controlled Study

Pierre Michelet, M.D.,* Xavier-Benoît D'Journo, M.D.,† Antoine Roch, M.D., Ph.D.,‡ Christophe Doddoli, M.D.,§ Valerie Marin, M.D.,‖ Laurent Papazian, M.D., Ph.D.,# Isabelle Decamps, M.D.,* Fabienne Bregeon, M.D., Ph.D.,** Pascal Thomas, M.D.,†† Jean-Pierre Auffray, M.D.‡‡

9 / 9 ml/kg (PEP=0) vs. 9 / 5 ml/kg (PEP=5)



Plasma



Anesthesiology 2006; 105:911–9

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Protective Ventilation Influences Systemic Inflammation after Esophagectomy

A Randomized Controlled Study

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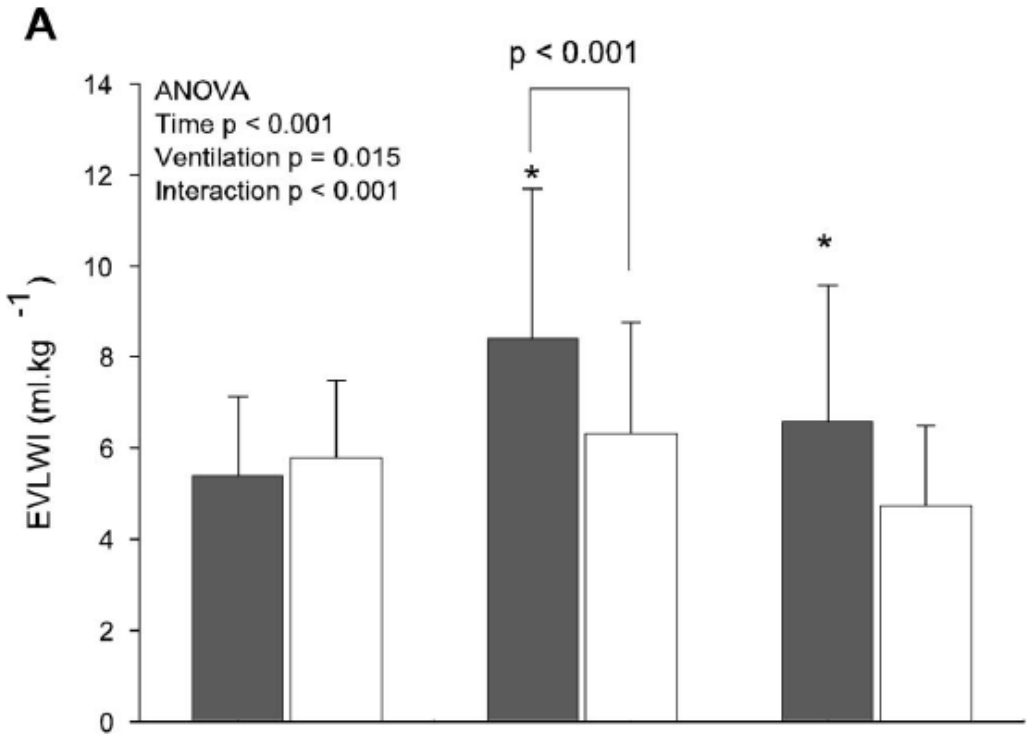
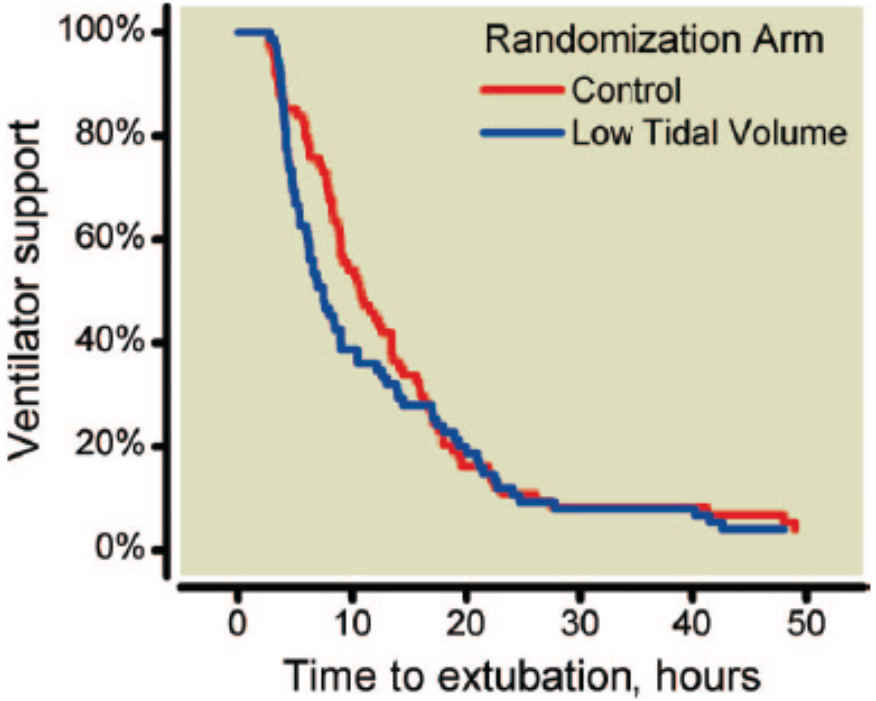


Anesthesiology 2006; 105:911–9

Influence of Low Tidal Volume Ventilation on Time to Extubation in Cardiac Surgical Patients

Sugantha Sundar, M.D.,* Victor Novack, M.D., Ph.D.,† Karinne Jervis, M.D.,‡
S. Patrick Bender, M.D.,‡ Adam Lerner, M.D.,§ Peter Panzica, M.D.,§ Feroze Mahmood, M.D.,§
Atul Malhotra, M.D.,‖ Daniel Talmor, M.D., M.P.H.#

149 patients : 6 vs. 10 ml/kg poids théo, PEP # 5



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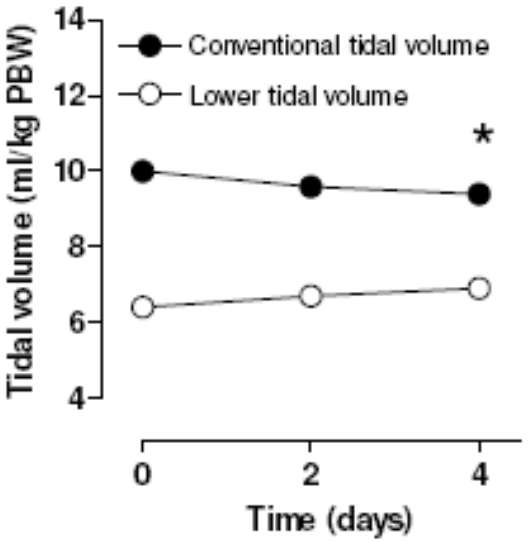
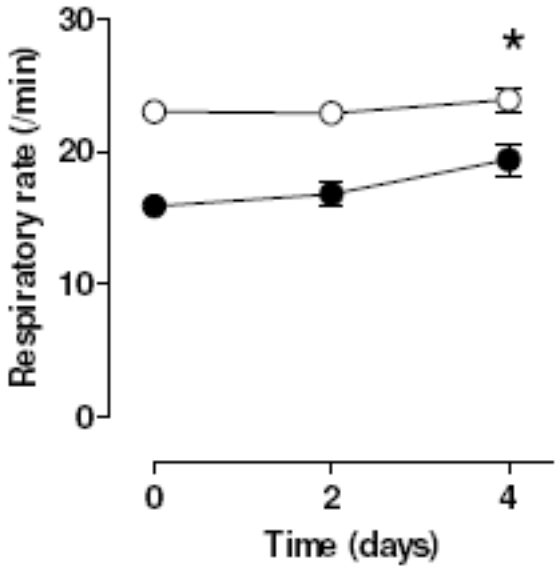
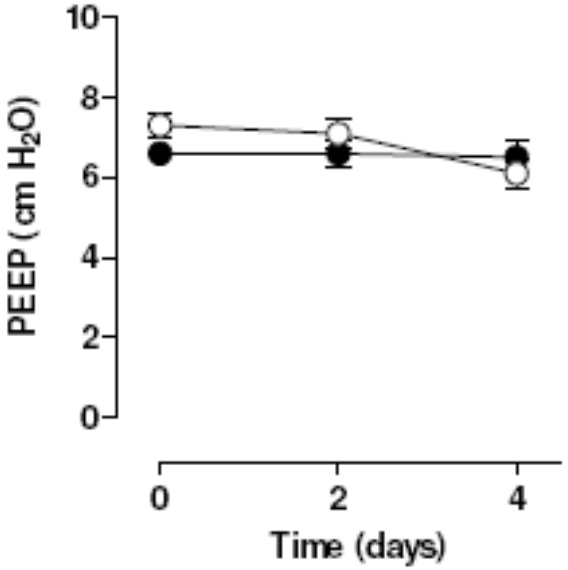
Ventilation with lower tidal volumes as compared with conventional tidal volumes for patients without acute lung injury: a preventive randomized controlled trial

Rogier M Determann[1,2], Annick Royakkers[3,4], Esther K Wolthuis[1,5], Alexander P Vlaar[1], Goda Choi[1,2], Frederique Paulus[1], Jorrit-Jan Hofstra[1,4], Mart J de Graaff[1], Johanna C Korevaar[6] and Marcus J Schultz*[1,7]

150 patients : 6 vs. 10 ml/kg poids théo







Critical Care 2010, **14**:R1

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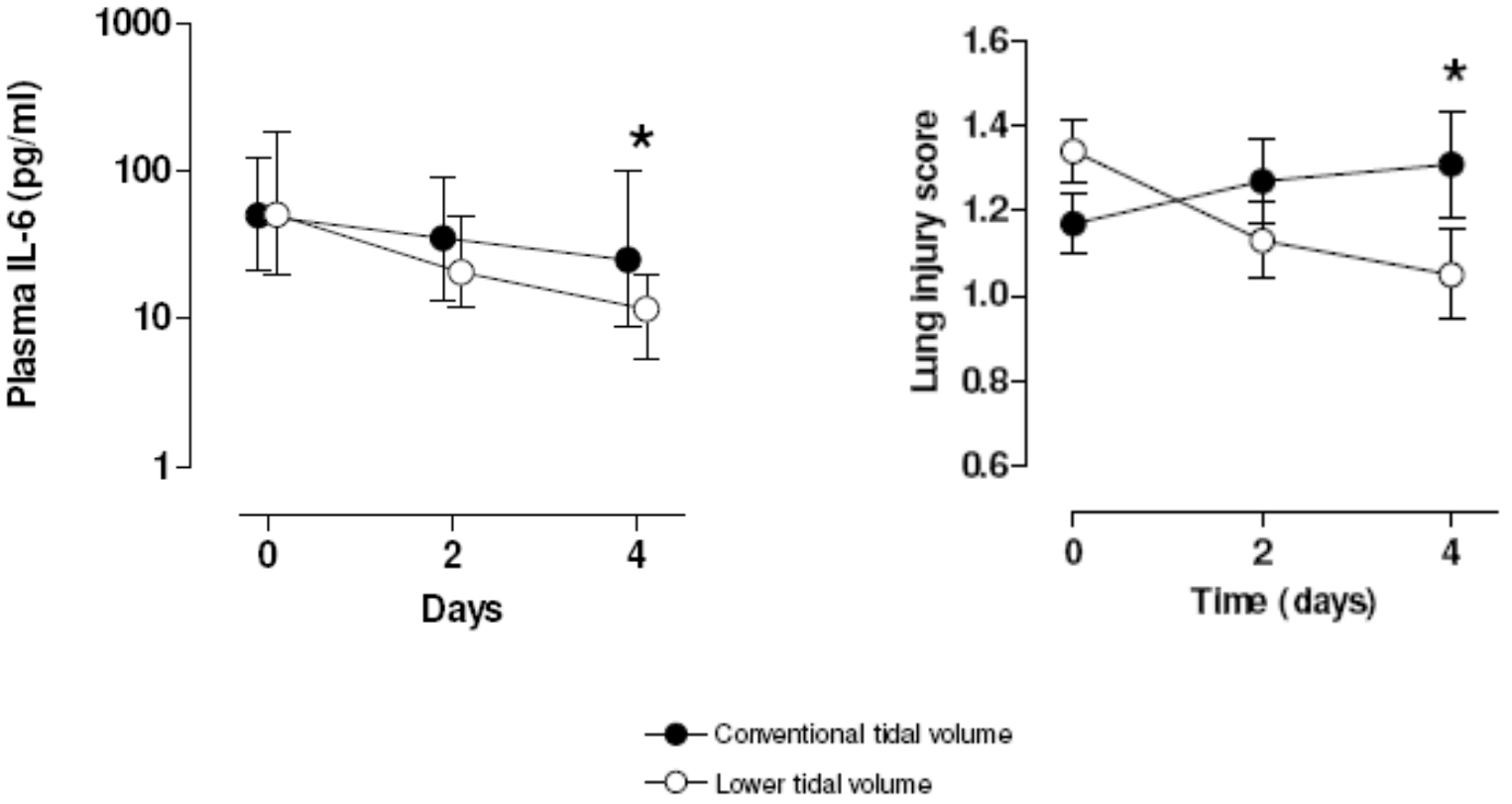
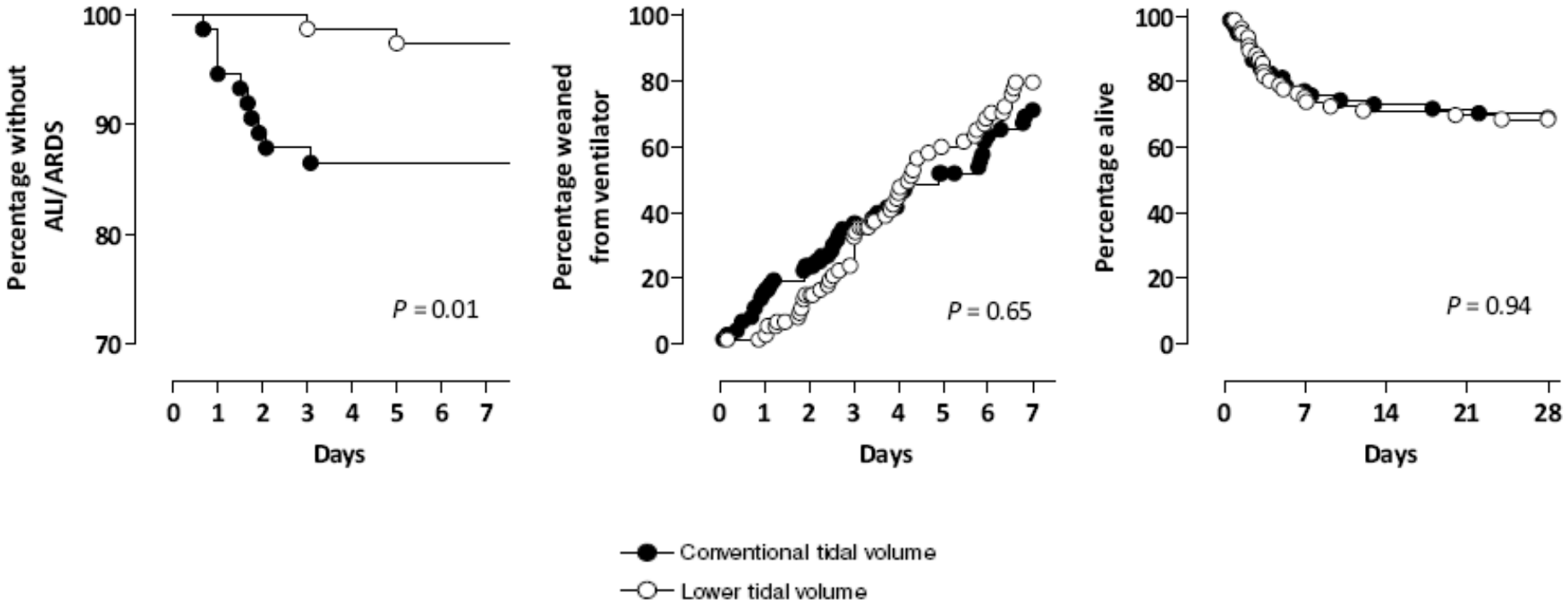


Critical Care 2010, **14**:R1

Ventilation with lower tidal volumes as compared with conventional tidal volumes for patients without acute lung injury: a preventive randomized controlled trial

Rogier M Determann[1,2], Annick Royakkers[3,4], Esther K Wolthuis[1,5], Alexander P Vlaar[1], Goda Choi[1,2], Frederique Paulus[1], Jorrit-Jan Hofstra[1,4], Mart J de Graaff[1], Johanna C Korevaar[6] and Marcus J Schultz*[1,7]



Critical Care 2010, **14**:R1

Ventilator-induced Lung Injury

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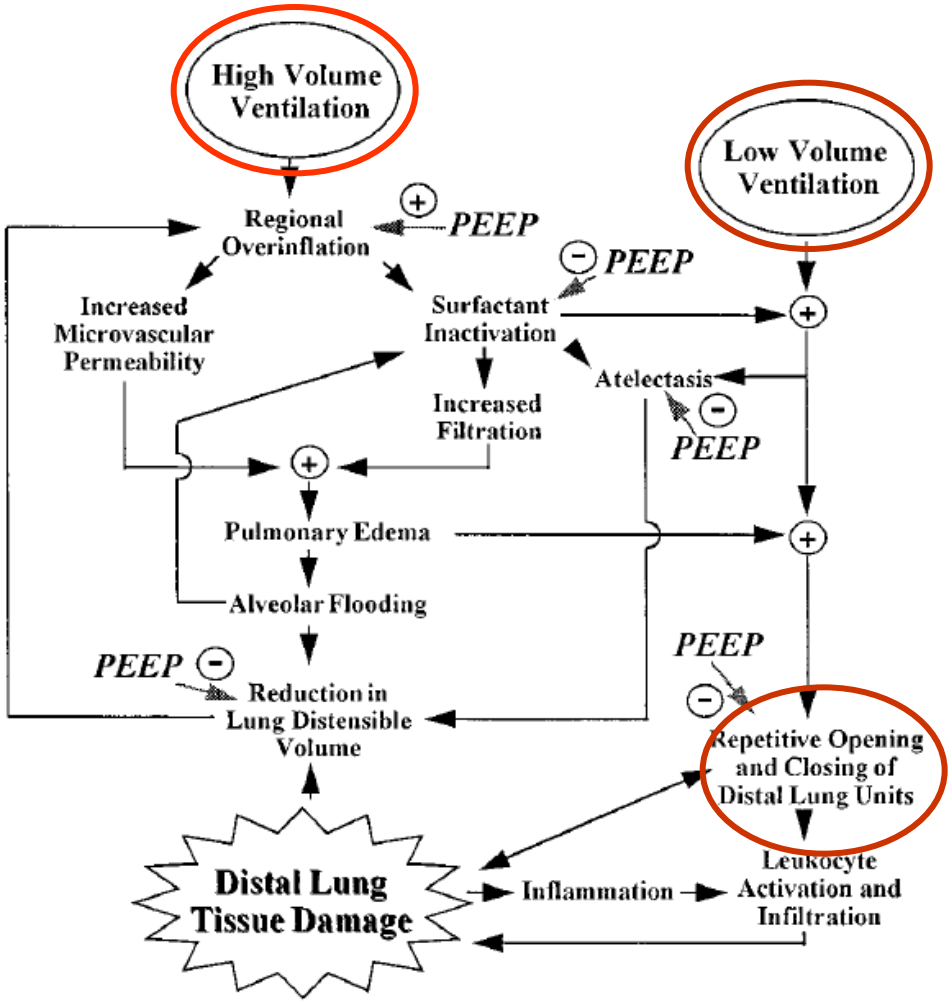
Lessons from Experimental Studies

DIDIER DREYFUSS and GEORGES SAUMON

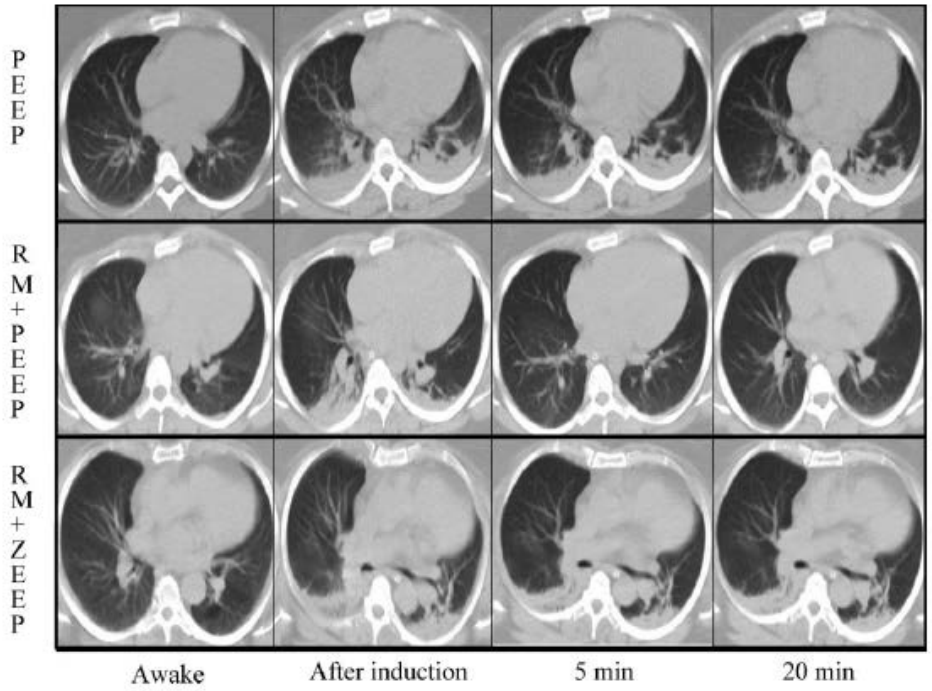


Am J Respir Crit Care Med Vol 157. pp 294–323, 1998

Prevention of Atelectasis in Morbidly Obese Patients during General Anesthesia and Paralysis

A Computerized Tomography Study

Henrik Reinius, M.D.,* Lennart Jonsson, M.D.,* Sven Gustafsson, M.D., Ph.D.,† Magnus Sundbom, M.D., Ph.D.,† Olov Duvernoy, M.D., Ph.D.,‖ Paolo Pelosi, M.D., Ph.D.,‡ Göran Hedenstierna, M.D., Ph.D.,§ Filip Fredén, M.D., Ph.D.*



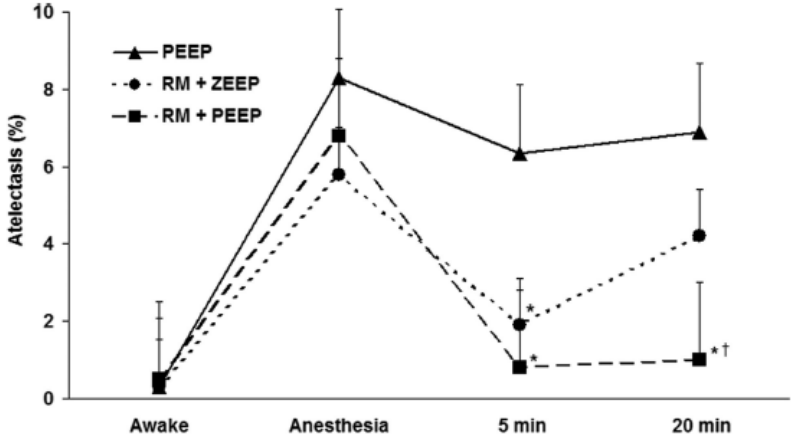


Fig. 3. Representative computerized tomography (CT). A CT scan 1 cm above the diaphragm in the three different groups at all four time points. Note the sustained effect of RM + PEEP and the transient effect of RM + ZEEP. PEEP = positive end-expiratory pressure; RM = recruitment maneuver; ZEEP = zero end-expiratory pressure.

Anesthesiology 2009; 111:979–87

www.ilar.com

Comparison of two ventilatory strategies in elderly patients undergoing major abdominal surgery

T. N. Weingarten[1], F. X. Whalen[1], D. O. Warner[1], O. Gajic[2], G. J. Schears[1], M. R. Snyder[3], D. R. Schroeder[4] and J. Sprung[1]*

Chirurgie abdominale majeure, Pts > 65 ans

"Recrut + Vt 6 + PEP 12" *vs.* "Vt 10"

	Control (n=20)	Recruitment (n=20)
Pa_{O_2}/FI_{O_2} (kPa)		
Baseline	47.2 (13.1)	41.5 (12.8)
60 min	40.0 (12.7)†	54.5 (10.7)†,*
Recovery room	44.8 (15.7)	40.0 (7.6)
Pa_{CO_2} (kPa)		
Baseline‡	5.3 (0.6)	6.2 (0.6)*
60 min	5.4 (0.6)	6.8 (0.7)†,*
Recovery room	6.0 (0.9)†	6.4 (0.6)

British Journal of Anaesthesia **104 (1):** 16–22 (2010)

www.ilar.com

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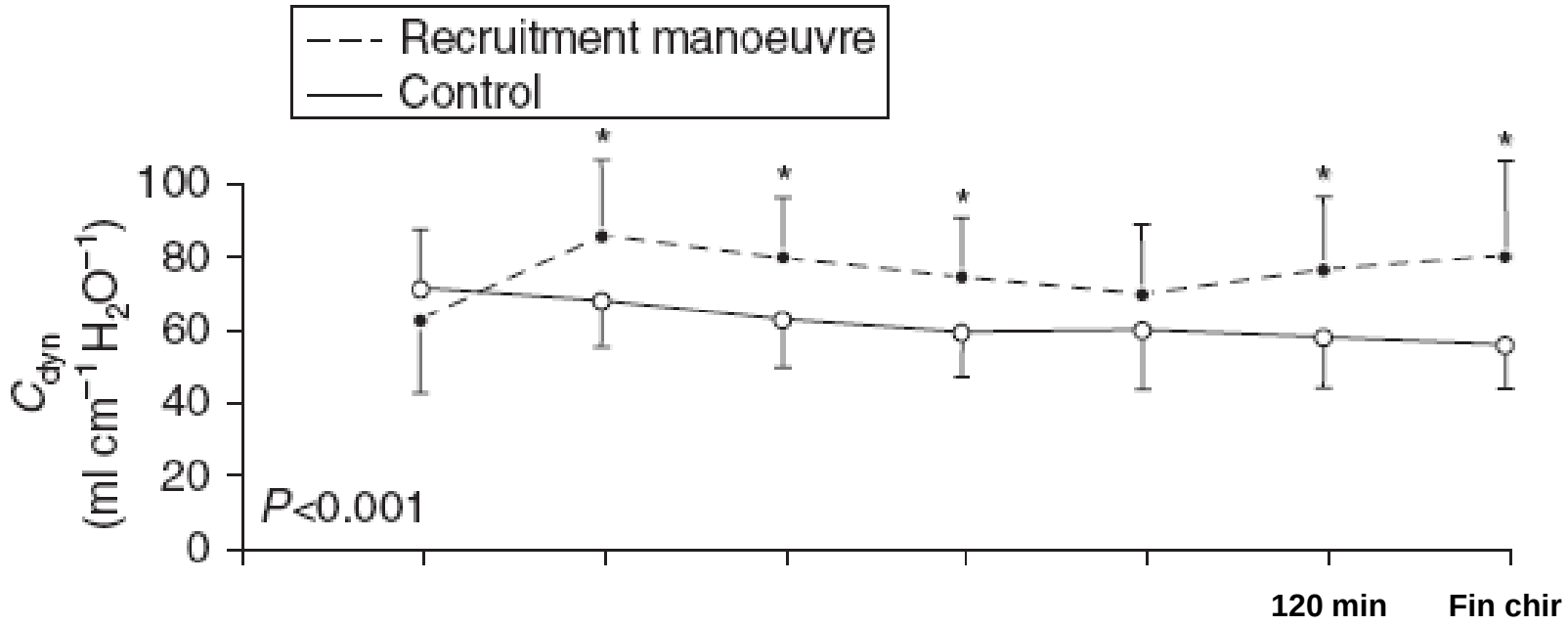

British Journal of Anaesthesia **104 (1):** 16–22 (2010)

www.ijar.com

Comparison of two ventilatory strategies in elderly patients undergoing major abdominal surgery

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	Control ($n=20$)	Recruitment ($n=20$)
IL-6 (pg ml^{-1})		
Baseline	3.3 (1.9–9.7)	2.8 (1.6–5.4)
Recovery room	113.0 (50.2–214.5)	70.0 (9.2–177.5)
Delta	109.6 (47.0–215.0)†	69.2 (7.4–175.0)†
IL-8 (pg ml^{-1})		
Baseline	7.1 (5.1–12.3)	7.0 (5.0–12.0)
Recovery Room	18.4 (6.3–60.7)	29.7 (5.0–83.2)
Delta	11.1 (1.0–49.0)†	22.5 (0.0–73.1)†

British Journal of Anaesthesia **104 (1):** 16–22 (2010)

r.com

Rationale and study design of PROVHILO - a worldwide multicenter randomized controlled trial on protective ventilation during general anesthesia for open abdominal surgery

Sabrine NT Hemmes[1*], Paolo Severgnini[2], Samir Jaber[3], Jaume Canet[4], Hermann Wrigge[5], Michael Hiesmayr[6], Edda M Tschernko[6], Markus W Hollmann[1], Jan M Binnekade[1], Göran Hedenstierna[7], Christian Putensen[9], Marcelo Gama de Abreu[8], Paolo Pelosi[10] and Marcus J Schultz[1]

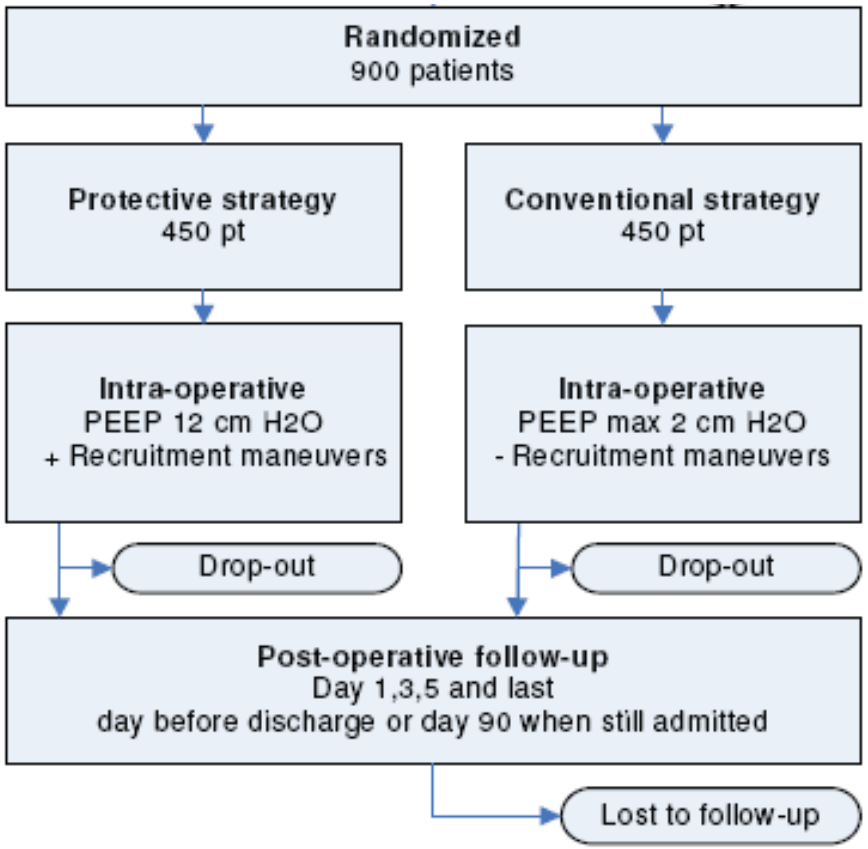
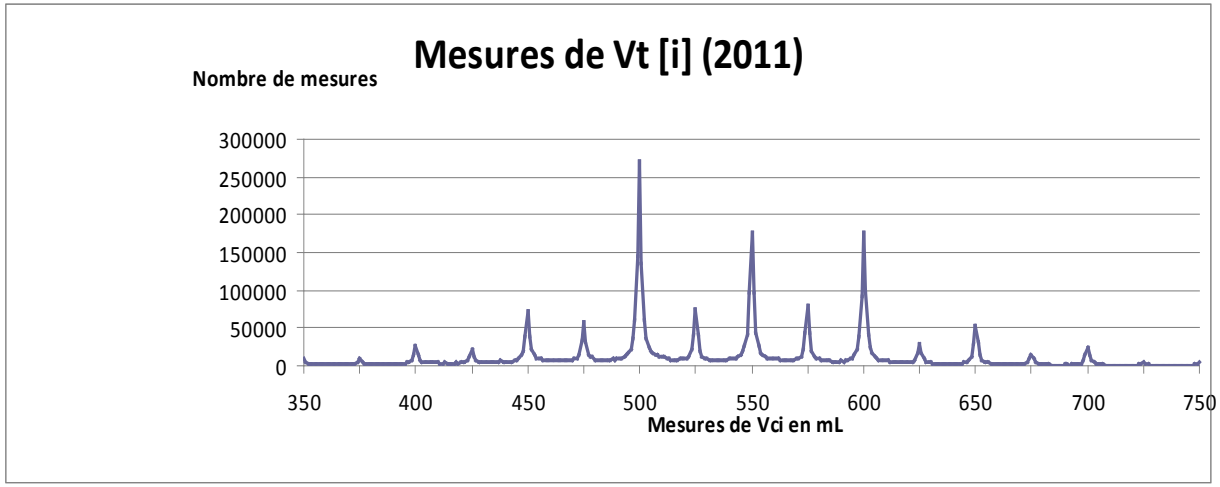
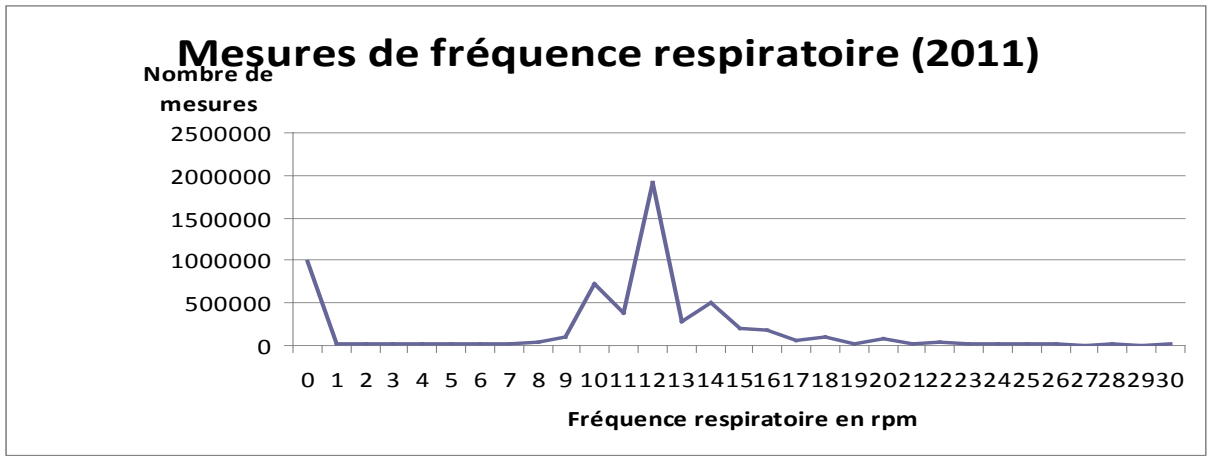


Figure 1 CONSORT diagram of PROVHILO. PEEP = positive end-expiratory pressure

Quid dans la "vraie vie"

(celle du CHRU de Lille!)





Infocentre DIANE; Données Antoine LAMER

Quid dans la "vraie vie"

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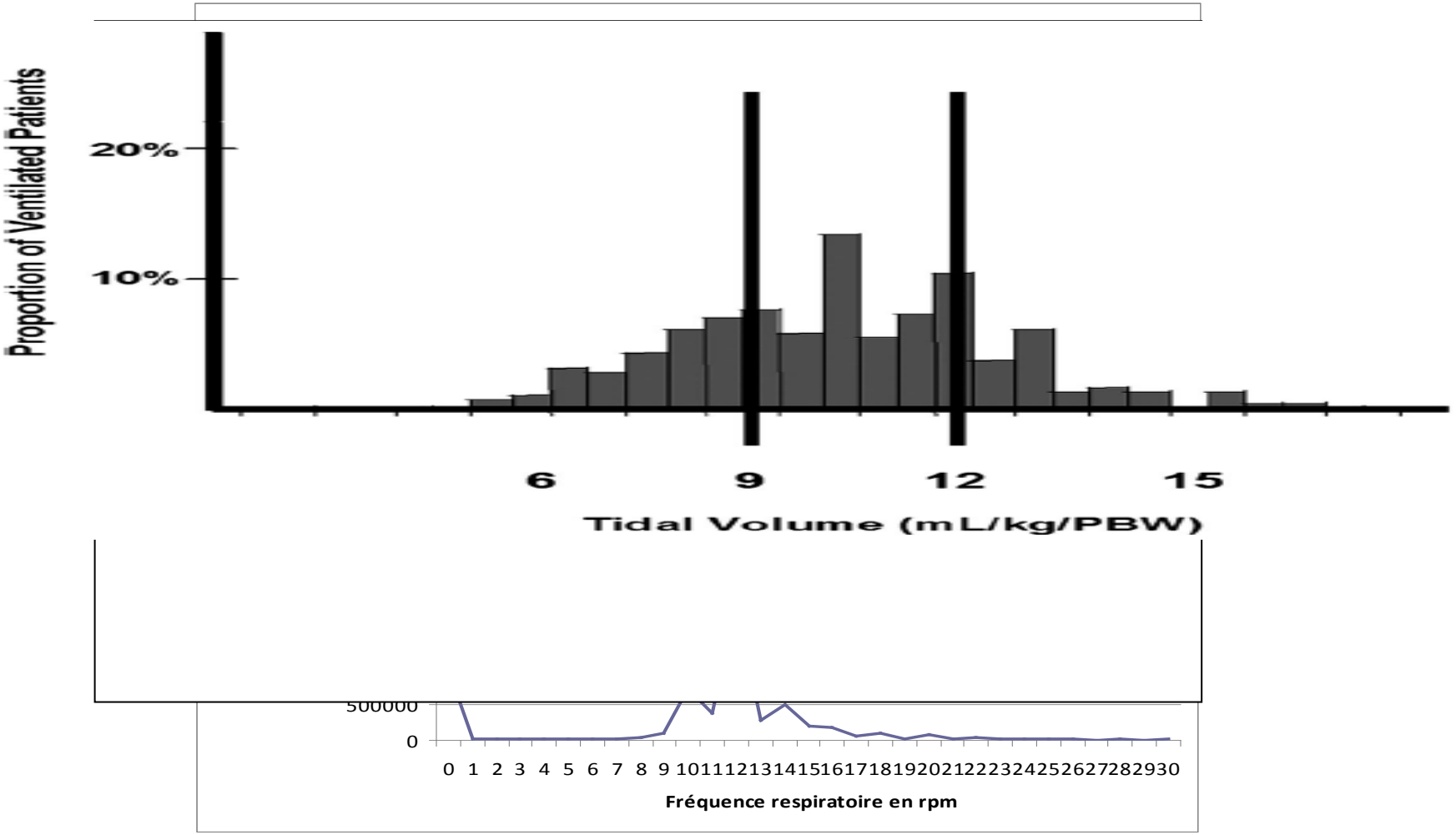

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Quid dans la "vraie vie"

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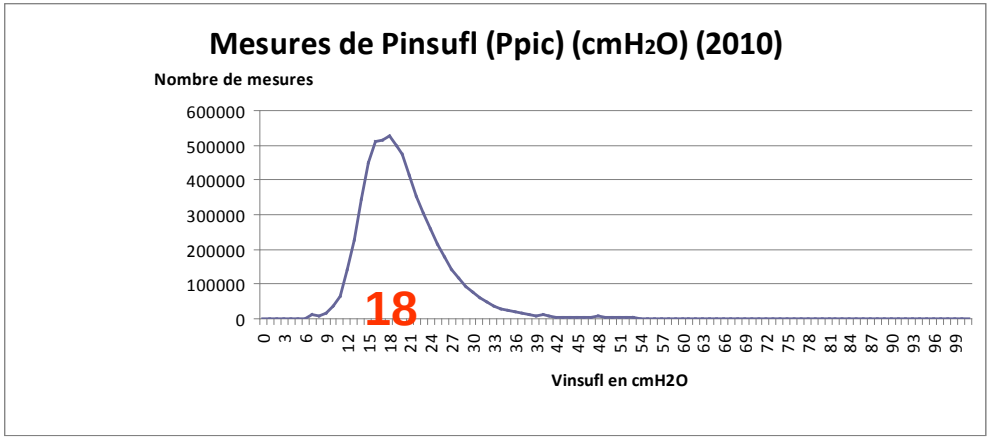
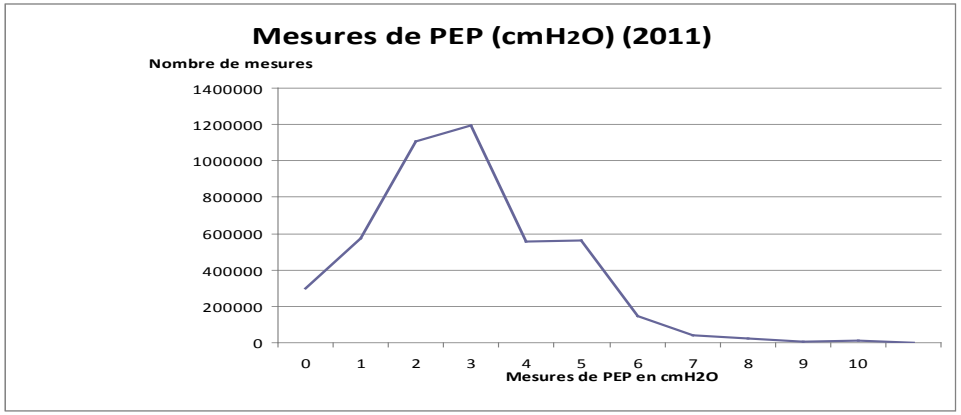




Infocentre DIANE; Données Antoine LAMER

SYNTHESE – CONCLUSION (1)

- Ventilation "protectrice"

  - ventilation la moins agressive possible (volume courant et Pplat)

  - prend en compte les effets secondaires de l'anesthésie (recrut / PEP)

- Au Bloc : 5-6 ml/kg poids théorique pour tous ?

  - peu d’arguments

  - nécessite probablement PEP > 10 cmH_2O (précédé de man. de recrutement systématique)

  - impact sur hémodynamique et balance liquidienne ?

SYNTHESE – CONCLUSION (2)

- "Standard" au bloc = 7-9 ml/kg poids théorique en routine
  - "principe de précaution"
  - réglé sur le poids théorique

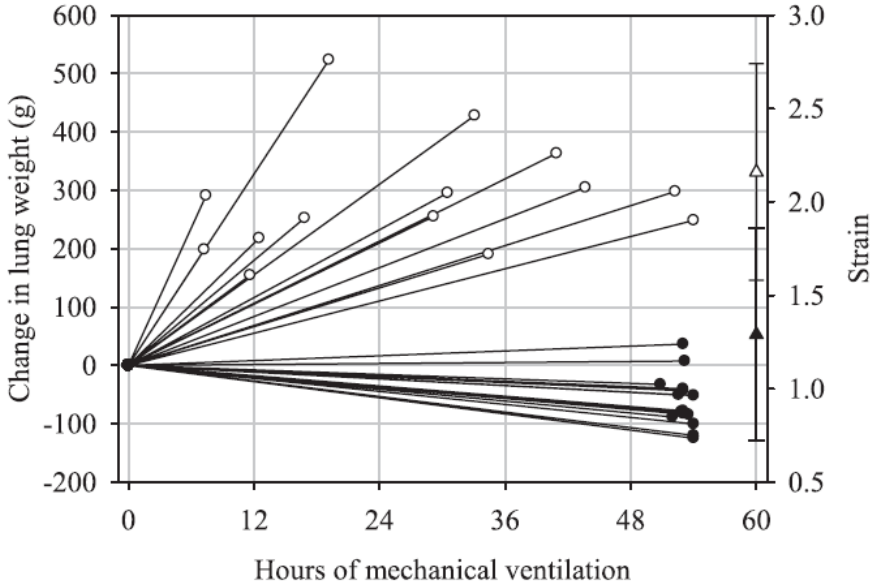
- Sauf ?
  - Ventilation unipulmonaire
  - Pplat élevée
  - Patient "à haut risque" (accumule les FdR)

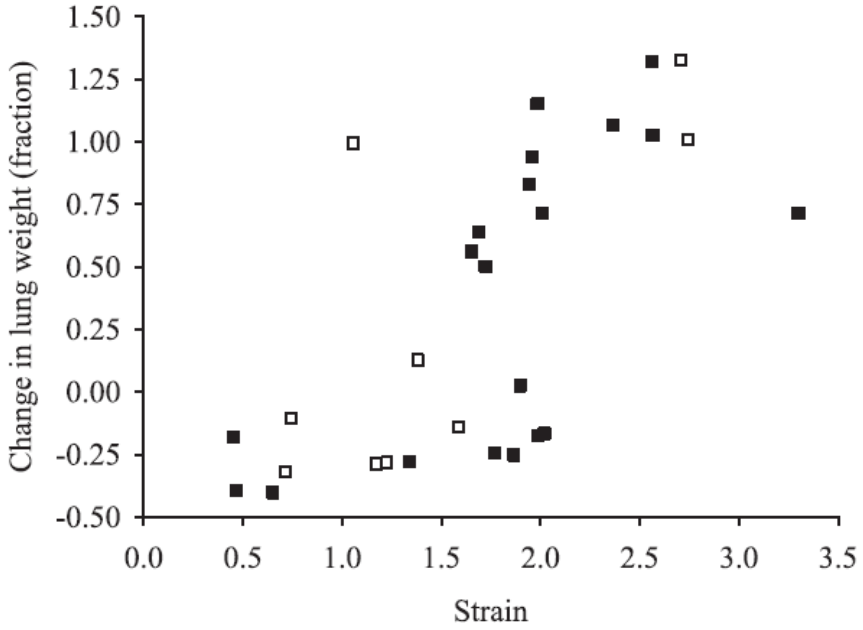
- Quel niveau de PEP ?

Lung Stress and Strain during Mechanical Ventilation

Any Safe Threshold?

Alessandro Protti[1], Massimo Cressoni[1], Alessandro Santini[1], Thomas Langer[1], Cristina Mietto[1], Daniela Febres[1], Monica Chierichetti[1], Silvia Coppola[1], Grazia Conte[2], Stefano Gatti[2], Orazio Leopardi[1], Serge Masson[3], Luciano Lombardi[4], Marco Lazzerini[4], Erica Rampoldi[5], Paolo Cadringher[1], and Luciano Gattinoni[1,6]





Am J Respir Crit Care Med Vol 183. pp 1354–1362, 2011

The Effects of Different Ventilatory Settings on Pulmonary and Systemic Inflammatory Responses During Major Surgery

Hermann Wrigge, MD*, Ulrike Uhlig, MSc, PhD†, Jörg Zinserling, MSc*, Elisabeth Behrends-Callsen*, Gunther Ottersbach*, Matthias Fischer, MD, PhD*, Stefan Uhlig, MSc, PhD†, and Christian Putensen, MD, PhD*

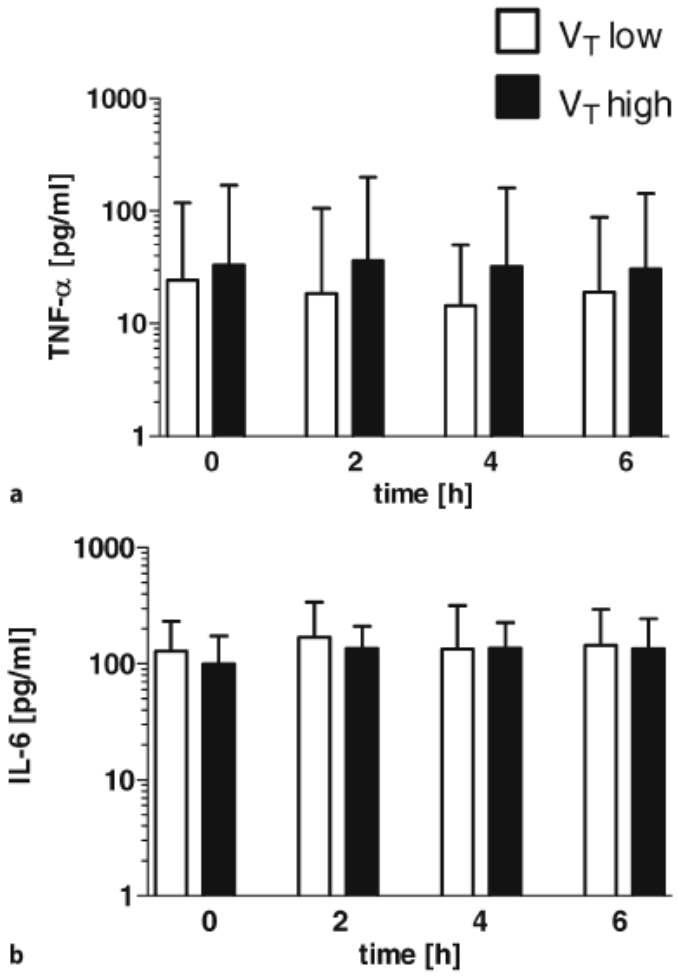
Table 3. Ventilatory and Respiratory Variables

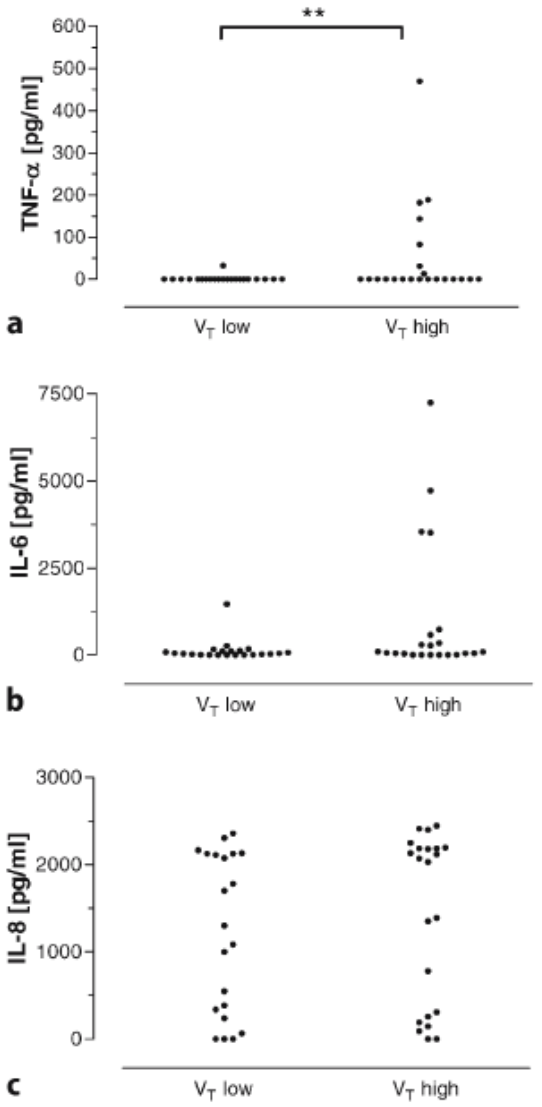
	Abdominal surgery		Thoracic surgery		Thoracic surgery, one-lung ventilation[a]	
	High V_T ZEEP	Low V_T PEEP	High V_T ZEEP	Low V_T PEEP	High V_T ZEEP	Low V_T PEEP
Rate (L/min)	6 ± 1	16 ± 4*	8 ± 1	16 ± 3*	8 ± 2	16 ± 6*
V_T (mL)	1339 ± 191	550 ± 69*	1016 ± 180	548 ± 72*	1028 ± 195	528 ± 93*
V_E (L/min)	9.2 ± 1.3	9.5 ± 2.7	8.5 ± 1.4	10.0 ± 1.8	8.5 ± 2.1	9.2 ± 2.0
T_I/T_{TOT}	0.35 ± 0.04	0.37 ± 0.07	0.38 ± 0.05	0.37 ± 0.07	0.34 ± 0.01	0.40 ± 0.07
Paw_{mean} (cm H_2O)	7 ± 1	13 ± 1*	6 ± 2	14 ± 2*	9 ± 2	15 ± 3*
Paw_{max} (cm H_2O)	22 ± 4	21 ± 3	19 ± 4	24 ± 5†	26 ± 4	28 ± 4
Pao_2/Fio_2 (mm Hg)	314 ± 62	306 ± 88	341 ± 162	411 ± 128	213 ± 72‡	242 ± 124§
$Paco_2$ (mm Hg)	36 ± 3	42 ± 3*	40 ± 5	44 ± 5	38 ± 4	44 ± 7†
pH	7.42 ± 0.03	7.35 ± 0.04*	7.40 ± 0.04	7.38 ± 0.04	7.41 ± 0.04	7.37 ± 0.05†

Anesth Analg 2004;98:775–81

Mechanical ventilation strategies and inflammatory responses to cardiac surgery: a prospective randomized clinical trial

Hermann Wrigge
Ulrike Uhlig
Georg Baumgarten
Jan Menzenbach
Jörg Zinserling
Martin Ernst
Daniel Drömann
Armin Welz
Stefan Uhlig
Christian Putensen

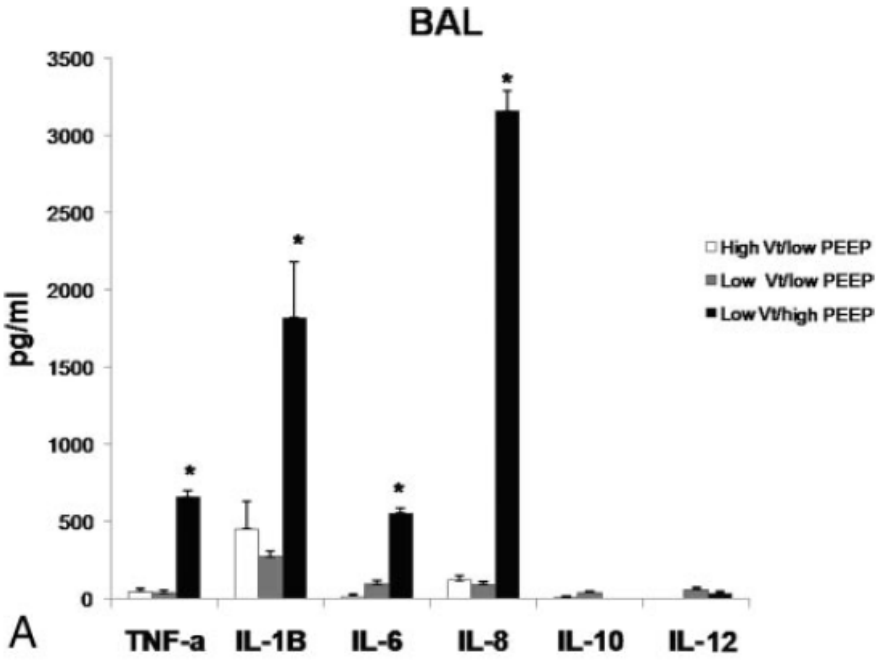


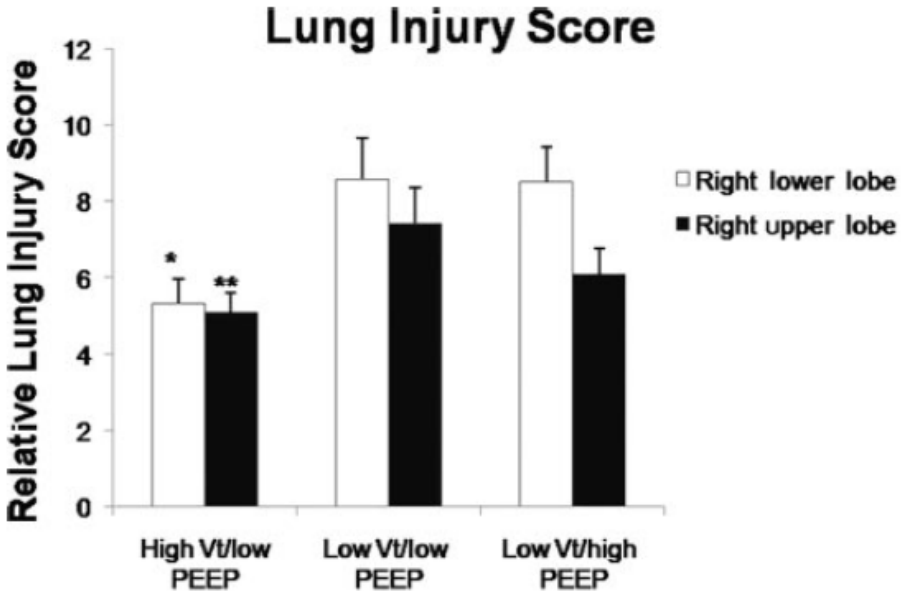


Intensive Care Med (2005) 31:1379–1387

Low Tidal Volume and High Positive End-Expiratory Pressure Mechanical Ventilation Results in Increased Inflammation and Ventilator-Associated Lung Injury in Normal Lungs

Caron M. Hong, MD, Da-Zhong Xu, MD, PhD, Qi Lu, MD, Yunhui Cheng, PhD, Vadim Pisarenko, MD, Danielle Doucet, MD, Margaret Brown, MSN, Seena Aisner, MD, Chunxiang Zhang, MD, PhD, Edwin A. Deitch, MD, and Ellise Delphin, MD, MPH





Anesth Analg 2010;110:1652–60