Mechanical Ventilation Strategies in Anesthesia

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ppelosi@hotmail.com
Conflicts of interest

I declare
NO conflicts of interest

Pelosi P for the PROVE Network (www.provenet.eu)
To perform Large multicenter clinical studies, randomized controlled trials, and meta-analyses

http://www.provenet.eu/

Pelosi P for the PROVE Network (www.provenet.eu)
• Introduction
• Lung changes during anesthesia
• Postoperative pulmonary complications
• Rationale of protective ventilation
• Tidal volume
• PEEP
• Plateau pressure
• Driving pressure
• Recruitment
• FiO₂
• PEEP post extubation
• Interactions between $V_T$ and PEEP – Pplat - $\Delta P$ – RR
• Assisted ventilation during surgery
• Conclusions

Pelosi P for the PROVE Network (www.provenet.eu)
ERAS Recommendations

No place for Intra-op Protective MV!

Pelosi P for the PROVE Network (www.provenet.eu)
Pelosi P for the PROVE Network (www.provenet.eu)
**Protective Ventilation during Anesthesia**

*Is It Meaningful?*

Göran Hedenstierna, M.D., Ph.D., Lennart Edmark, M.D., Ph.D.

<table>
<thead>
<tr>
<th><strong>FRC awake: 2,800 ml</strong></th>
<th><strong>FRC during anesthesia: 2,400 ml</strong></th>
<th><strong>EELV in ARDS: 500 ml</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>VT 500 ml → 7 ml/kg or 18% of FRC</td>
<td>VT 500 ml → 7 ml/kg or 21% of FRC</td>
<td>VT 700 ml → 10 ml/kg or 140% of EELV</td>
</tr>
<tr>
<td>VT 700 ml → 10 ml/kg or 25% of FRC</td>
<td>VT 700 ml → 10 ml/kg or 29% of FRC</td>
<td>VT 420 ml → 6 ml/kg or 84% of EELV</td>
</tr>
</tbody>
</table>

“Without knowing how successful the protective ventilation is during anesthesia...and if any positive effects remain in the postoperative period, reduction in postoperative pulmonary complications can hardly be attributed to protective ventilation.”

Pelosi P for the PROVE Network (www.provenet.eu)
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Pelosi P for the PROVE Network (www.provenet.eu)
Atelectasis, Anesthesia and Post-Operative period


Awake

Anesthesia, spontaneous breathing

Anesthesia, and paralysis

Spontaneous breathing 48 hrs postop

Pelosi P for the PROVE Network (www.provenet.eu)
Atelectasis and General Anesthesia

Lundquist H. et al. (1995) Acta Radiologica 36; 626-632

Pelosi P for the PROVE Network (www.provenet.eu)
Atelectasis and lung function in the postoperative period


Pelosi P for the PROVE Network (www.provenet.eu)
Post-Op. Atelectasis: Myth or Reality?
Güldner A. et al. Anesthesiology 2015 June 29 [Epub Ahead of Print]

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Pelosi P for the PROVE Network (www.provenet.eu)
Incidence of mortality and morbidity related to postoperative lung injury in patients who have undergone abdominal or thoracic surgery


Pelosi P for the PROVE Network (www.provenet.eu)
Epidemiology, Practice of Ventilation and Outcome for Patients at Increased Risk of PPCs (LAS VEGAS) – an Observational Study in 29 Countries

The LAS VEGAS Investigators - Eur J Anaesthesiol 2017; 34:492–507

- 146 hospitals across 29 countries
- 9,864 patients
- Patients at increased risk - 28.4%

Pelosi P for the PROVE Network (www.provenet.eu)
Epidemiology, Practice of Ventilation and Outcome for Patients at Increased Risk of PPCs (LAS VEGAS) – an Observational Study in 29 Countries

The LAS VEGAS Investigators - Eur J Anaesthesiol 2017; 34:492–507

Pelosi P for the PROVE Network (www.provenet.eu)
To Predict the Risk of PPCs: “ARISCAT” Score


13 % (score 26-44) – 54 % (score >45) risk to develop PPCs

<table>
<thead>
<tr>
<th>ARISCAT inclusion criteria</th>
<th>Criteria values</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in years</td>
<td>≤ 50</td>
<td>51-80</td>
</tr>
<tr>
<td>Preoperative SpO2 %</td>
<td>≥ 96</td>
<td>91-95</td>
</tr>
<tr>
<td>Respiratory infection (last month)</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Preoperative anemia (≤ 10 g/dL)</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

Pelosi P for the PROVE Network (www.provenet.eu)
Post-operative atelectasis and Post-operative SatO₂

Ball L, Bluth T, Guldner A et al. 2016 (in preparation)

Pelosi P for the PROVE Network (www.provenet.eu)
Post-operative atelectasis and Post-operative SatO$_2$

Ball L, Bluth T, Guldner A et al. 2016 (in preparation)

Pelosi P for the PROVE Network (www.provenet.eu)
PPCs & preoperative SpO$_2$


Pelosi P for the PROVE Network (www.provenet.eu)
The accuracy of postoperative, noninvasive Air-Test to diagnose atelectasis in healthy patients after surgery

Ferrando C et al. BMJ Open 2017;7:e015560

<table>
<thead>
<tr>
<th>AUC (95% CI)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-Test (n=59) 0.90 (0.82 to 0.98) 82.6</td>
<td>87.8</td>
<td></td>
</tr>
</tbody>
</table>

The presence of atelectasis was confirmed by CT scans in all patients (30/30) with positive and in 5 patients (17%) with negative Air-Test results.

Based on the Air-Test, postop atelectasis (CT>2%) was present in 36% of the patients.

Pelosi P for the PROVE Network (www.provenet.eu)
How to early recognize sepsis: qSOFA?

Singer M et al. JAMA. 2016;315(8):801-810
Seymour CW et al. JAMA. 2016;315(8):762-774

Quick SOFA (qSOFA)

In ED and ward settings

1) Respiratory rate ≥ 22 breaths/min
2) Altered mentation
3) Systolic blood pressure ≤ 100 mmHg
4) Sat O_2 in air < 94%

THAM = Tachypnea, Hypotension, Altered Mentation

- additional tests to evaluate organ function
- prompt intervention
- increased surveillance / transfer to ICU?

Pelosi P for the PROVE Network (www.provenet.eu)
National Early Warning Score (NEWS)
To assess the acute-illness severity

<table>
<thead>
<tr>
<th>PHYSIOLOGICAL PARAMETERS</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiration Rate</td>
<td>≤8</td>
<td></td>
<td>9 - 11</td>
<td>12 - 20</td>
<td></td>
<td>21 - 24</td>
<td>≥25</td>
</tr>
<tr>
<td>Oxygen Saturation</td>
<td>≤91</td>
<td>92 - 93</td>
<td>94 - 95</td>
<td>≥96</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any Supplemental Oxygen</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>≤35.0</td>
<td>35.1 - 36.0</td>
<td>36.1 - 38.0</td>
<td>38.1 - 39.0</td>
<td>≥39.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic BP</td>
<td>≤90</td>
<td>91 - 100</td>
<td>101 - 110</td>
<td>111 - 119</td>
<td>≥220</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart Rate</td>
<td>≤40</td>
<td>41 - 50</td>
<td>51 - 90</td>
<td>91 - 110</td>
<td>111 - 130</td>
<td>≥131</td>
<td></td>
</tr>
<tr>
<td>Level of Consciousness</td>
<td></td>
<td>A</td>
<td></td>
<td>V, P, or U</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NEWS scores</th>
<th>Clinical risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Low</td>
</tr>
<tr>
<td>Aggregate 1–4</td>
<td></td>
</tr>
<tr>
<td>RED score* (Individual parameter scoring 3)</td>
<td>Medium</td>
</tr>
<tr>
<td>Aggregate 5–6</td>
<td></td>
</tr>
<tr>
<td>Aggregate 7 or more</td>
<td>High</td>
</tr>
</tbody>
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Pelosi P for the PROVE Network (www.provenet.eu)
Intraoperative mechanical ventilation in patients with non-injured lungs: time to talk about tailored protective ventilation?

Lorenzo Ball, Paolo Pelosi


Pelosi P for the PROVE Network (www.provenet.eu)
Protect the Lungs during Abdominal Surgery

It May Change the Postoperative Outcome

Vidal Melo M.F., Eikermann M. Anesthesiology 2013; 118:1254-7
Brismar B. et al. Anesthesiology. 1985 Apr;62(4):422-8
Ball L et al. Minerva Anestesiol. 2017 May 19. (Epub ahead of print)


Pelosi P for the PROVE Network (www.provenet.eu)
Individualized ventilatory strategy: ameliorate lung injury while preserving physiology

S. Wirth* and S. Schumann
Freiburg, Germany
*E-mail: steffen.wirth@uniklinik-freiburg.de

Intraoperative ventilation: improving physiology, or preventing harm?

S. Hemmes1-*, A. Serpa Neto2, M. Gama de Abreu3, P. Pelosi4 and M. Schultz1
1 Amsterdam, Netherlands, 2 Sao Paulo, Brazil, 3 Dresden, Germany, and 4 Genoa, Italy
*E-mail: s.hemmes@amc.nl
MV & Postoperative Respiratory Disorders

Ball L. and Pelosi P. Minerva Anestesiol. 2016 Mar;82(3):265-7
Ball L et al. Minerva Anestesiol. 2017 May 19. (Epub ahead of print)

Pelosi P for the PROVE Network (www.provenet.eu)
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Pelosi P for the PROVE Network (www.provenet.eu)
Dose–Response Relationship Between PPCs and $V_T$ during Surgery


LOWER $V_T$
REDUCES PPCs (2,127 patients)

Pelosi P for the PROVE Network (www.provenet.eu)
LAS VEGAS – Practice of Ventilation in ORs Worldwide

The LAS VEGAS Investigators - Eur J Anaesthesiol 2017; 34:492–507

- international observational study
- 8,241 patients
- 8.1 [7.2–9.1] mL/kg PBW
- \( V_T > 8 \text{ ml/Kg in 40\% of patients} \)

Pelosi P for the PROVE Network (www.provenet.eu)
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Pelosi P for the PROVE Network (www.provenet.eu)
PEEP

IS SO EXCITING!

... I WON'T BORE YOU WITH THE DETAILS

Pelosi P for the PROVE Network (www.provenet.eu)
Protective Mechanical Ventilation during Surgery: RCTs

Futier E. et al. N Engl J Med
2013;369:428-37

PROVEnet investigators. The Lancet
2014; Aug 9;384:495-503

PEEP/RM Group (n=445)
no PEEP/RM Group (n=449)

Postoperative Pulmonary Complications (%)

- $V_T$ 10-12 ml/Kg PBW – PEEP $0 \text{ cmH}_2\text{O}$
- $V_T$ 6-8 ml/Kg PBW – PEEP 6-8 cmH$_2$O
RM 30 cmH$_2$O – 30 s – every 30 min

- $V_T$ 7 ml/Kg PBW – PEEP $\leq 2 \text{ cmH}_2\text{O}$
- $V_T$ 7 ml/Kg PBW – PEEP 12 cmH$_2$O
RM 30 cmH$_2$O 3 times

Pelosi P for the PROVE Network (www.provenet.eu)
Dose–Response Relationship Between PPCs and PEEP during Surgery

PEEP DOES NOT REDUCE PPCs (2,127 patients)

Pelosi P for the PROVE Network (www.provenet.eu)
Intraoperative protective mechanical ventilation and risk of postoperative respiratory complications: hospital based registry study
Ladha K et al. BMJ 2015;351:h3646

Postoperative Pulmonary Complications

Pelosi P for the PROVE Network (www.provenet.eu)
## Intraoperative Complications (%, n/N)

The PROVE Network investigators. The Lancet 2014 Aug 9;384(9942):495-503

<table>
<thead>
<tr>
<th></th>
<th>Higher PEEP N= 445</th>
<th>Lower PEEP N=449</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rescue for de-saturation</td>
<td>2 (11/442)</td>
<td>8 (34/445)</td>
<td>&lt; 0·0008</td>
</tr>
<tr>
<td>Hypotension</td>
<td>46 (205/441)</td>
<td>36 (162/449)</td>
<td>0·0016</td>
</tr>
<tr>
<td>Vasoactive drugs</td>
<td>62 (274/444)</td>
<td>51 (228/445)</td>
<td>0·0016</td>
</tr>
<tr>
<td>New arrhythmias</td>
<td>3 (12/442)</td>
<td>1 (5/445)</td>
<td>0·09</td>
</tr>
<tr>
<td>Organ perforation</td>
<td>1 (4/444)</td>
<td>1(4/444)</td>
<td>1</td>
</tr>
</tbody>
</table>

Pelosi P for the PROVE Network ([www.provenet.eu](http://www.provenet.eu))
Respiratory System Mechanics During Low Versus High Positive End-Expiratory Pressure in Open Abdominal Surgery: A Substudy of PROVHILO RCT


Pelosi P for the PROVE Network (www.provenet.eu)
Ventilation with High or Low PEEP does not affect postop pulmonary functional tests (PROVHILO substudy)


Effects of PEEP: 2 cmH$_2$O vs 12 cmH$_2$O

Pelosi P for the PROVE Network (www.provenet.eu)
Kinetics of plasma biomarkers for inflammation or lung injury in surgical patients with and without post-operative pulmonary complications (PROVHILO substudy)


**PPCs vs no PPCs:**

**INCREASED** Lung injury biomarkers

- **open symbols, green box (no PPCs)**
- **closed symbols, red box (PPCs)**

**High PEEP vs Low PEEP:**

**INCREASED** Lung injury biomarkers

- **open symbols, green box (low PEEP)**
- **closed symbols, red box (high PEEP)**

Pelosi P for the PROVE Network (www.provenet.eu)
Individualized PEEP in obese patients
Nestler C et al  Br J Anaesth 2017 (Epub Ahead of Print)

Bariatric surgery, N = 50 patients

\[ V_T = 8 \text{ mL/kg PBW} \]
- \( PEEP = 5 \text{ cmH}_2\text{O} \)
- \( PEEP \) according to EIT (18.5 ± 5.6 cmH\(_2\)O)

Pelosi P for the PROVE Network (www.provenet.eu)
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Nestler C et al  Br J Anaesth 2017 (Epub Ahead of Print)

Bariatric surgery, N = 50 patients

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- PEEP = 5 cmH$_2$O
- PEEP according to EIT (18.5 ± 5.6 cmH$_2$O)

Pelosi P for the PROVE Network (www.provenet.eu)
SUBPHENOTYPES IN PATIENTS UNDERGOING GENERAL ANESTHESIA FOR OPEN ABDOMINAL SURGERY: An unbiased cluster analysis from the PROVHILO trial
Serpa-Neto A et al. for the PROVE Network Investigators (submitted)

Association between subphenotypes assignment and clinical outcomes

**Table:**

<table>
<thead>
<tr>
<th>Subphenotype</th>
<th>PPC (n)</th>
<th>Severe PPC (n)</th>
<th>EPC (n)</th>
<th>Hospital LOS in survivors (days)</th>
<th>In-hospital mortality (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subphenotype 1 (n = 170)</td>
<td>105 / 168 (62.5)</td>
<td>79 / 168 (47.0)</td>
<td>101 / 168 (60.1)</td>
<td>15 (11 – 28)</td>
<td>3 / 157 (1.9)</td>
</tr>
<tr>
<td>Subphenotype 2 (n = 40)</td>
<td>17 / 38 (44.7)</td>
<td>10 / 38 (26.3)</td>
<td>21 / 38 (55.3)</td>
<td>12 (9 – 18)</td>
<td>1 / 38 (2.6)</td>
</tr>
<tr>
<td>Subphenotype 3 (n = 10)</td>
<td>1 / 10 (10.0)</td>
<td>1 / 10 (10.0)</td>
<td>1 / 10 (10.0)</td>
<td>8 (8 – 14)</td>
<td>0 / 10 (0.0)</td>
</tr>
</tbody>
</table>

*P value:
- PPC: 0.001
- Severe PPC: 0.007
- EPC: 0.007
- Hospital LOS in survivors: 0.001
- In-hospital mortality: 0.659

Pelosi P for the PROVE Network ([www.provenet.eu](http://www.provenet.eu))
• international study
• 8,241 patients
• PEEP 4.0 [0–5] cm H$_2$O
• PEEP 0 and 5 cm H$_2$O most frequently used

Pelosi P for the PROVE Network (www.provenet.eu)
Future RCTs on Intraoperative Ventilation

- PROBESE trial (obese patients): high vs. low PEEP, during lower $V_T$ ventilation

- PROTHOR trial (OLV): high vs. low PEEP, during lower $V_T$ ventilation

http://www.provenet.eu/

Pelosi P for the PROVE Network (www.provenet.eu)
Rationale and study design for an individualized perioperative open lung ventilatory strategy (iPROVE): study protocol for a RCT


Pelosi P for the PROVE Network (www.provenet.eu)
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Intraoperative protective mechanical ventilation and risk of postoperative respiratory complications: hospital based registry study
Ladha K et al. BMJ 2015;351:h3646

Pelosi P for the PROVE Network (www.provenet.eu)
• international study
• 8,241 patients
• Pplat 15.5 [13.0-18.5] cm H$_2$O
• Ppeak 17.5 [15.0-21.0] cm H$_2$O
• Ppeak > 20 cm H$_2$O (Pplat > 18 cmH$_2$O) in 25-30% of patients
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Pelosi P for the PROVE Network (www.provenet.eu)
\[ \Delta P = P_{\text{plat,rs}} - \text{PEEP} = \frac{\text{VT}}{Cst} = \frac{\text{VT}}{EELV} \]
Driving Pressure (ΔP,rs) & PPCs

Higher driving pressures increase the risk of PPCs

2.679 patients from 15 RCTs


Pelosi P for the PROVE Network (www.provenet.eu)
Higher Driving Pressures (> 12 cmH₂O) Increase the Risk of PPCs

69,265 patients from observational trial

Adjusting for patient body mass index, age, gender, ASA

Pelosi P for the PROVE Network (www.provenet.eu)
• international study
• 8,241 patients
• $\Delta P$ 12.0 [10.0-15.0] cm H$_2$O
• $\Delta P > 12$ cm H$_2$O in 50% of patients

Pelosi P for the PROVE Network (www.provenet.eu)
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Pelosi P for the PROVE Network (www.provenet.eu)
Recruitment manoeuvre during anesthesia

Reinius H et al. Anesthesiology 2009; 111:979-987

Güldner A. et al. Anesthesiology. 2015 Sep;123(3):692-713

Pelosi P for the PROVE Network (www.provenet.eu)
Manual Recruitment with/without CPAP
Sustained Inflation Manoeuvre (single step)
Recruitment (multi-step)

- PEEP step increase 2 cmH₂O
- PEEP max 20 cmH₂O
- Pinsp max 35 cmH₂O
- Resp/Passo n° breaths at increasing PEEP
- Resp@Max n° breaths at PEEPmax

<table>
<thead>
<tr>
<th>Pinsp max</th>
<th>PEEP max</th>
<th>ΔPressione</th>
<th>Resp@Max</th>
<th>Resp/Passo</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 cmH₂O</td>
<td>20 cmH₂O</td>
<td>8 cmH₂O</td>
<td>8 cmH₂O</td>
<td>6 cmH₂O</td>
</tr>
</tbody>
</table>
Lung recruitment and positive airway pressure before extubation does not improve oxygenation in the post-anaesthesia care unit: a RCT


PEEP 10 cmH2O + RM (40 cm H2O for 40 seconds)

Pelosi P for the PROVE Network (www.provenet.eu)
Routine Bag – Squeezing RMs are associated with higher incidence of Unplanned O\textsubscript{2} and Severe PPCs

Ball L et al for PROVEnet and LAS VEGAS-ESA investigators

LAS VEGAS – Recruitment in obese patients

Pelosi P for the PROVE Network (www.provenet.eu)
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Pelosi P for the PROVE Network (www.provenet.eu)
Oxygen concentration and characteristics of progressive atelectasis formation during anaesthesia


Pelosi P for the PROVE Network (www.provenet.eu)
Post-operative atelectasis – a randomised trial investigating a ventilatory strategy and low oxygen fraction during recovery


No significant effect of FiO₂ (with PEEP) before extubation

Pelosi P for the PROVE Network (www.provenet.eu)
The effects of high perioperative inspiratory oxygen fraction for adult surgical patients


No effects on surgical infections of higher or lower perioperative FiO$_2$

doi:10.1093/bja/aex176

Intraoperative fraction of inspired oxygen: bringing back the focus on patient outcome

L. Ball$^1$, A. B. Lumb$^2$ and P. Pelosi$^{1,*}$

$^1$Department of Surgical Sciences and Integrated Diagnostics, IRCCS AOU San Martino-IST, University of Genoa, Genoa, Italy and $^2$Department of Anaesthesia, St James’s University Hospital, Leeds, UK

Heterogeneity: Tau$^2$ = 0.06; Chi$^2$ = 9.94, df = 4 (P = 0.04); $I^2$ =60%
Test for overall effect: Z = 0.98 (P = 0.33)

No effects on mortality of higher or lower perioperative FiO$_2$

Pelosi P for the PROVE Network (www.provenet.eu)
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- Introduction
- Lung changes during anesthesia
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- Rationale of protective ventilation
- Tidal volume
- PEEP
- Plateau pressure
- Driving pressure
- Recruitment
- FiO₂
- PEEP post extubation
- Interactions between Vₜ and PEEP – Pplat - ∆P – RR
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- Conclusions

Pelosi P for the PROVE Network (www.provenet.eu)
Small Tidal Volumes, Positive End-expiratory Pressure, and Lung Recruitment Maneuvers during Anesthesia

Good or Bad?

Göran Hedenstierna, M.D., Ph.D.

“[The] focus has been on the lung during anesthesia, whereas emergence from anesthesia to wakefulness may be of even greater importance.”

Pelosi P for the PROVE Network (www.provenet.eu)
A ventilation strategy during general anaesthesia to reduce postoperative atelectasis


No significant effect of FiO₂ and PEEP before extubation
No significant effect of FiO₂ and PEEP after extubation

Pelosi P for the PROVE Network (www.provenet.eu)
Effect of early postextubation high-flow nasal cannula vs conventional oxygen therapy on hypoxemia in patients after major abdominal surgery (OPERA): a multicentre RCT


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Pelosi P for the PROVE Network (www.provenet.eu)
Practice of Ventilation in ORs

The LAS VEGAS Investigators - Eur J Anaesthesiol 2017; 34:492–507

Pelosi P for the PROVE Network (www.provenet.eu)
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Pelosi P for the PROVE Network (www.provenet.eu)
Spontaneous breathing during anaesthesia: first, do no harm

GORDON B DRUMMOND
Pelosi P for the PROVE Network (www.provenet.eu)
Smart Ventilation Control (SVC)

Safe
Lung Protective Ventilation during Anaesthesia

Spontaneous
Maximise Spontaneous Breathing during Anaesthesia

Simple
The Intuitive Approach to Ventilation

Pelosi P for the PROVE Network (www.provenet.eu)
How does SVC operate?

Course of a SVC session

Adaptation Phase
- Controlled*

Ventilation Management
- Controlled
- Augmented
- Encourage SB

Recovery Phase
- Prepare Extubation

* SVC is using the target ranges of “Controlled” during adaptation phase

Intubation

Extubation

Pelosi P for the PROVE Network (www.provenet.eu)
What is Smart Ventilation Control?

Main Idea

- Select "ventilation goal" depending on procedure
- Check target ranges for tidal volume and etCO2
- Smart Ventilation Control will continuously monitor and adjust the ventilation

Pelosi P for the PROVE Network (www.provenet.eu)
**How does Smart Volume Control work?**

**Ventilation Goals: Definition**

<table>
<thead>
<tr>
<th>Ventilation Goal</th>
<th>Explanation</th>
<th>“Old World”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controlled</td>
<td>Applicable if no spontaneous breathing is desired</td>
<td>PC (BIPAP)</td>
</tr>
<tr>
<td>Augmented</td>
<td>Applicable if spontaneous breathing is OK, but should not be encouraged</td>
<td>PC (BIPAP) + PS</td>
</tr>
<tr>
<td>Encourage SB</td>
<td>Applicable if spontaneous breathing is desired</td>
<td>PS</td>
</tr>
</tbody>
</table>

Pelosi P for the PROVE Network (www.provenet.eu)
SVC – A simple and patient oriented way to achieve spontaneous breathing

Zeus® Infinity® Empowered with SVC setting: Encourage SB

Traditional Approach settings (average # of steps):
1. Switch Sync on in Pressure Control
2. Adjust trigger sensibility
3. Reduce mandatory frequency
4. Switch to Pressure Support
5. Set Apnea frequency
6. Adjust Pressure Support level
7. Reduce stepwise the pressure support

Pelosi P for the PROVE Network (www.provenet.eu)
Smart Ventilation Control: User Interface

Main Parameters

**Height:** Needed for IBW as Smart Ventilation Control operates with VT in ml/kg

**Target Ranges:**
VT in ml/kg and etCO2
Ranges predefined for normal patients. Need only to be adapted for special patients (e.g. COPD)
Default settings can be chosen by hospital.
There are different target ranges for each ventilation goal.

**Ventilation goal:**
main parameter to control the ventilation through whole procedure

**PEEP:**
The PEEP is the only parameter not adjusted by Smart Ventilation Control

Pelosi P for the PROVE Network ([www.provenet.eu](http://www.provenet.eu))
etCO2 Waveform:
In the standard etCO2 waveform the target range for etCO2 will be shown.

The range will always be shown if SVC is active.

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Pelosi P for the PROVE Network (www.provenet.eu)
“Permissive Atelectasis” during General Anesthesia
Pelosi P, Rocco PRM, de Abreu MG (Crit Care 2018 – in press)

Pelosi P for the PROVE Network (www.provenet.eu)
The Funeral for Positive End-Expiratory Pressure …better known as PEEP

“It was a dream for generations of anesthesiologists”
Conclusions

- Mechanical ventilation setting during surgery affects postoperative outcome (in patients “at risk”)

- V\textsubscript{T} 6-8 ml/Kg PBW/IBW

- PEEP 2-5 cmH\textsubscript{2}O w/o RM, but not yielding increased $\Delta P$

- PEEP higher than 5 cmH\textsubscript{2}O:
  - Surgery longer than 3 hours
  - Laparoscopy in Trendelenburg position
  - BMI equal or higher than 35 kg/m\textsuperscript{2}

- Higher PEEP induces hemodynamic impairment and need of fluid overload

- P\textsubscript{plat} < 16 cmH\textsubscript{2}O and $\Delta P$ (P\textsubscript{plat}-PEEP) < 13 cmH\textsubscript{2}O

- FiO\textsubscript{2} up to 80% does not affect post operative function

- Controlled mechanical ventilation is often unnecesssary and may be harmful: think about spontaneous breathing and servo-controlled systems!
Protective Mechanical Ventilation During Surgery To Improve Postoperative Outcome

JUST DO IT!

Pelosi P for the PROVE Network (www.provenet.eu)