



## Effects of two different ventilation strategies on respiratory mechanics during robotic-gynecological surgery

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### ABSTRACT

It is unknown which is the best ventilatory approach in patients scheduled for gynecological robotic surgery in Deep Trendelenburg position in terms of respiratory mechanics. 40 patients were enrolled: 20 patients received a standard ventilation and 20 patients received a protective ventilation. Gas exchanges, respiratory mechanics and hemodynamic parameters were recorded. No significant differences were found between the two groups in terms of respiratory mechanics. In both groups, there was a significant reduction of static compliance between Baseline and Extubation Time ( $p < 0.01$ ), and a significant increase of pulmonary pressure at the same times ( $p < 0.01$ ). In both groups, a significant reduction of pH ( $p < 0.01$ ) and a significant increase of PaCO<sub>2</sub> ( $p < 0.01$ ) were observed between Baseline and Extubation Time. At the Extubation time, PaCO<sub>2</sub> was significantly higher during protective ventilation compared to standard ventilation. In this particular surgical setting, a protective ventilation strategy did not improve the respiratory mechanics compared to the standard ventilation strategy and was ineffective on post-operative gas exchanges.

### 1. Introduction

For many years, mechanical ventilation during general anesthesia was managed using high tidal volumes (V<sub>t</sub>) and without applying Positive End Expiratory Pressure (PEEP). This ventilatory strategy aimed to avoid alveolar collapse, to improve ventilation-perfusion mismatch and to reduce the oxygen fraction of the inspired mixture (Bendixen et al., 1963). The potential harmful effects of short term intra-operative ventilation are increasingly recognized (Schultz et al., 2007). The mechanical ventilation can cause a pulmonary complication defined Ventilator-Induced Lung Injury (VILI), a condition characterized by alveoli overdistension or repetitive opening and closing of atelectatic lung area (Dreyfuss, Saumon, 1998; Lu, 2013).

Recently, two conventional meta-analyses of observational studies and randomized controlled trials on intra-operative ventilation have supported the use of lung protective ventilation, with lower V<sub>t</sub> and higher levels of PEEP in order to prevent VILI and post-operative pulmonary complications (Serpa Neto et al., 2012; Hemmes et al., 2013). Laparoscopy is a well-established procedure for gynecologic surgery, which needs an induced pneumoperitoneum to facilitate the surgical manipulation, and it is often performed in Trendelenburg position (the

head down body position). The increase of abdominal pressure related to both pneumoperitoneum and Trendelenburg position has demonstrated to impair the respiratory function, mainly inducing atelectasis area in the dependent lung regions (Fahy et al., 1995; Hedenstierna, Edmark, 2005; Strang et al., 2009; Valenza et al., 2010). The hypothesis that a protective ventilation has some benefits and should be applied in this particular surgical setting, has been widely demonstrated (Rothen et al., 1993; Perilli et al., 2000; Hedenstierna, Edmark, 2005; Meininger et al., 2005; Maracajá-Neto et al., 2009; Valenza et al., 2010).

Recently, the concept of “lung protective ventilation strategy” has been adapted from acute respiratory distress syndrome to the anesthesiologic management. In fact, the application of an “open lung” strategy, consisting in a recruitment maneuvers (RMs) followed by the consequent application of PEEP, has been suggested to be able to improve oxygenation through the re-expansion of pneumoperitoneum-induced atelectasis area. The effects of open lung ventilatory strategy on respiratory mechanics and post-operative pulmonary complications in healthy patients underwent robotic-laparoscopic surgery in Deep Trendelenburg position, have not been specifically investigated.

The aim of the present study was to compare the effects of two ventilatory strategies (Protective mechanical ventilation versus

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Conventional mechanical ventilation), during general anesthesia for robotic laparoscopic gynecological surgery in Deep Trendelenburg position, on respiratory mechanics and post-operative pulmonary complications in patients with normal respiratory function.

## 2. Materials and methods

### 2.1. Study population

Forty consecutive patients, scheduled for elective gynecological robotic surgery, were enrolled from September 2014 to September 2015 in our Hospital. The study was approved by the Hospital Ethics Committee (number 10398/14) and a written informed consent was obtained from all subjects on the day of surgery, according to the Italian Regulations.

Inclusion criteria were: age more than 18 years, American Society of Anesthesiology physical status I and II, absence of pulmonary and heart disease, and surgery lasting more than 3 h.

Exclusion criteria were: Body Mass Index > 40 Kg/m<sup>2</sup>, neuromuscular diseases, respiratory and/or cardiovascular impairment, urgent surgery.

Irrespective of study group, all patients received a protocol guided anesthesia management, consisting in intravenous fentanyl (1–2 µ/kg) and propofol (2 mg/kg) at induction; thereafter, the anesthesia was maintained with propofol by Target-controlled Infusion (TCI) (3–6 mcg/ml), analgesia was provided with remifentanyl by TCI (3–5 ng/ml) or fentanyl (3–5 µ/kg) intravenous boluses. The infusion rate of propofol was titrated to obtain a Bispectral Index (BIS) value between 40 and 60. Patients were curarized with rocuronium bromide (0,8 mg/kg at the induction and subsequent intravenous boluses to target a Train of Four 0/4 until 30 min before the end surgery). An infusion of balanced crystalloid solutions, 8 ml/kg before the induction of anesthesia and 2–4 ml/kg/h intraoperatively, was given to all patients enrolled.

### 2.2. Study design and procedure

The ventilation protocol consisted in a volume-controlled mechanical ventilation through Servo I Ventilator (Maquet, LLC, NJ, USA), inspiratory to expiratory ratio of 1:2, and a respiratory rate adjusted to normocapnia (end-tidal carbon dioxide partial pressure between 30 and 40 mmHg). After obtained informed consent, the patients were randomly assigned to:

- 1 Standard ventilation (SV) group, Vt of 10 ml/kg of Ideal Body Weight (IBW) and a PEEP of 5 cmH<sub>2</sub>O
- 2 Protective ventilation (PV) group, Vt of 6 ml/kg of IBW and a PEEP of 8–10 cmH<sub>2</sub>O, associated to recruitment maneuvers (RMs).

IBW was calculated according to a predefined formula: 50 + 0,91(height [cm] – 1524) for men and 455 + 0,91 (height [cm] – 1524) for women (Brower et al., 2000).

The randomization in two study groups was performed by a computer-generated list with random block size (Three Randomization Plan Generators. Available from URL: [randomization.com](http://randomization.com), 2018).

RMs were performed only in hemodynamic stable conditions and at pre-set moments: after the induction of anesthesia, after any disconnection from the mechanical ventilator, each 1hourinterval during the surgical procedure and immediately before extubation. RMs were performed in Pressure Control mode as follows: the limit of peak inspiratory pressure was set at 45 cmH<sub>2</sub>O and the pressure control was set at 30 cmH<sub>2</sub>O, therefore three consecutive thirty seconds lasting inspiratory pauses were performed. At the end of RMs, respiratory rate, inspiratory to expiratory ratio, inspiratory pause, and Vt were set back at the previous values.

### 2.3. Measurements

Air Flow (V<sup>˙</sup>) was measured with a heated pneumotachograph (Fleisch no. 2; Fleisch, Lausanne, Switzerland), inserted between the Y-piece of the ventilator circuit and the endotracheal tube. The pneumotachograph was linear over the experimental range of flow. Volume was obtained by numerical integration of the flow signal. Airway pressure (Paw) was measured proximal to the endotracheal tube with a pressure transducer with a differential pressure of ± 100 cm H<sub>2</sub>O (Digima Clic-1, ICU-Lab system, KleisTek Engineering, Bari, Italy). The end-inspiratory and end-expiratory occlusions were performed through specific maneuver of Servo I ventilator.

All signals were acquired, amplified, and digitized at 100 Hz, then recorded on a dedicated personal computer and analyzed through specific software (ICU Lab 2,7, KleisTEK, Engineering, Bari, Italy).

Respiratory Resistance and Compliance were calculated using a standardized procedure.<sup>17</sup> Following end-inspiratory occlusion, there was an immediate drop of the airway pressure from a maximal value (Pmax) to airway pressure at zero flow (P1), followed by a further decrease to plateau pressure (P2). The plateau pressure usually arrived within 3 s. Therefore, airway pressure 3 s after occlusion was taken as the static end-inspiratory elastic recoil pressure (P2) of the respiratory system. The use of the interrupter method for the measurement of respiratory mechanics allows possible quantification of the airway and viscoelastic properties of the respiratory system. The difference between Pmax and P1 divided by flow provides major information about minimal airway resistance (Rmin), while the difference between P1 and P2 (ΔP) divided by flow stands for viscoelastic resistance or Pendelluft effect of the respiratory system (ΔR). Maximal respiratory resistance (Rmax) is the sum of Rmin and ΔR. The inspiratory volume divided by P2-Total PEEP yields respiratory system compliance (Chou et al., 2009).

Mechanical respiratory measurements and arterial blood gases were performed immediately after intubation (Baseline, BS), after pneumoperitoneum (AP), at the first two hours after pneumoperitoneum (AP1 and AP2) and before extubation (Ext). A further arterial blood gas sample was taken 1 h after extubation.

For each patient enrolled in the study, the Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) for post-operative pulmonary complications was calculated (Mazo et al., 2014).

The day after the surgical procedure, clinical patient examination and Chest X-ray were performed, to detect eventual pulmonary adverse events (Smetana et al., 2006; Canet et al., 2010) (arterial oxygen-hemoglobin saturation measured with pulse oximetry (SpO<sub>2</sub>) < 90% on room air and/or requiring prolonged post-operative oxygen therapy, a new lung consolidation at Chest X-ray).

### 2.4. Statistical analysis

Primary endpoint of the study was the comparative evaluation of respiratory variables (Compliance, Airway Resistances and Flow) between the two different ventilatory strategies applied. Secondary endpoints were the evaluation of gas exchange, need for prolonged post-operative oxygen supplementation, new lung consolidation at Chest X-ray, admission in post-operative Intensive Care Unit and Hospital Length of Stay in both study groups.

Power analysis was based using data from the study of Wirth et al., 2017. And reporting the lowest improvement in compliance during Protective ventilation with RMNs (10 ml/cmH<sub>2</sub>O) coupled with the highest estimate of Variance (SD, 10 mmHg). The sample size calculated has been 20 patients in each study group. The α and β errors for the sample size has been chosen as 0.05 and 90%, respectively. All data was expressed as mean ± standard deviation (DS). A 2-side t-test to compare the respiratory variables and gas exchange between the two groups tested has been used. The analysis of variance for repeated measures in each group was performed by one-way ANOVA. When detected, post hoc analysis was performed using Bonferroni Test. P

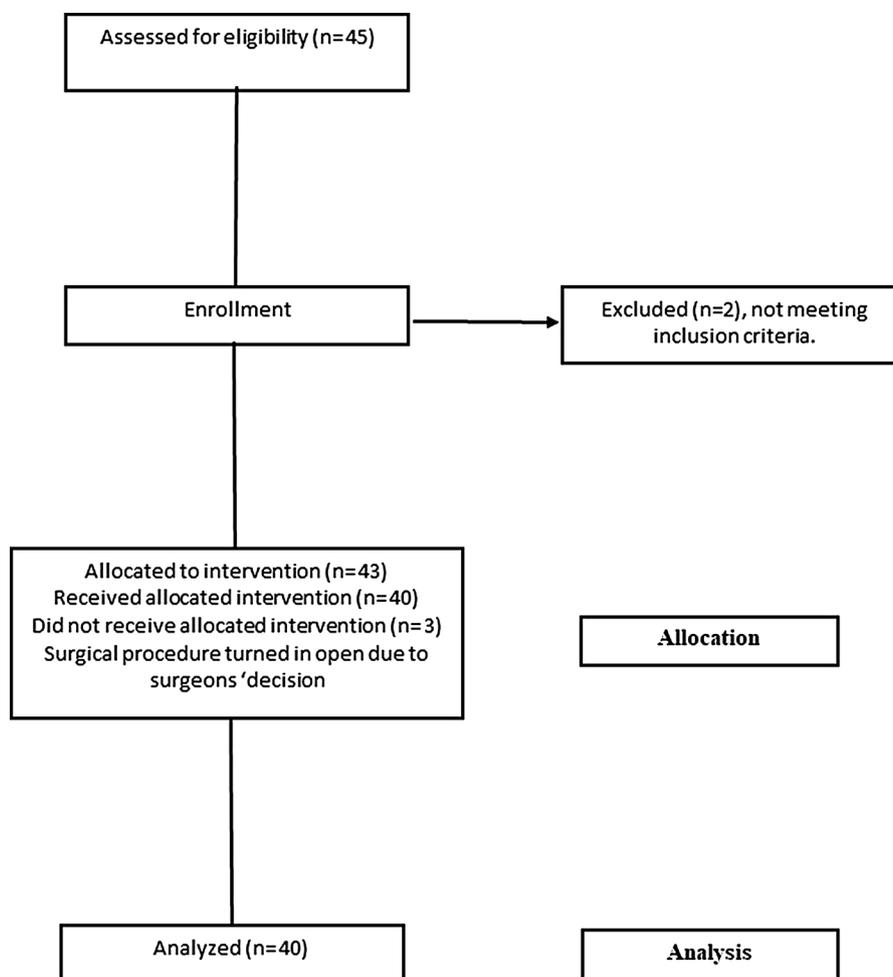


Fig. 1. CONSORT Flow Diagram.

values  $\leq 0,05$  were considered statistically significant.

### 3. Results

All the forty patients enrolled, completed the study (Fig. 1). Demographic data and surgical times are showed in Table 1. These data were comparable in the two study groups. No difference in terms of smoking history between the two groups was detected (SV 25% vs PV 20%). In both study groups, no patients suffered from asthma or Chronic Obstructive Pulmonary Disease (COPD).

No significant differences were found in both ventilation groups in terms of ARISCAT score ( $36,8 \pm 4,09$  in SV group and  $37,55 \pm 4,7$  in PV group). Assessing the ARISCAT Score, all patients enrolled in the study showed the same moderate risk of post-operative pulmonary complications.

No significant differences between SV and PV groups in terms of Static Compliance, Respiratory Resistances and Flow were observed (Table 2). In both groups, a significant reduction of Static Compliance between the Baseline and the intraoperative measurements until the ExtubationTime, was detected (Fig. 2). Before Extubation, increased values of static compliance in both groups were detected ( $p < 001$ ), even if significantly lower than BS ones in both groups ( $67,40 \pm 2148$  ml/cmH<sub>2</sub>O vs  $5714 \pm 15,32$  ml/cmH<sub>2</sub>O in SV group and  $6571 \pm 2047$  ml/cmH<sub>2</sub>O vs  $5148 \pm 9,50$  ml/cmH<sub>2</sub>O in PV group;  $p < 001$  respectively).

Concerning the airway pressures, a significant increase of all values (P1, P2 and Pmax) after Pneumoperitoneum ( $p < 001$ ) was observed in both groups, and all airway pressure parameters returned to the

**Table 1**  
Patients characteristics.\*

SV Group	PV Group	<i>p</i> -value	
Age (yr)	$562 \pm 12,76$	$55,57 \pm 13,99$	ND
Weight (kg)	$6665 \pm 10,88$	$70,05 \pm 14,89$	ND
Height (cm)	$16320 \pm 6,68$	$164,7 \pm 7,29$	ND
Ideal Weight (kg)	$5533 \pm 6,08$	$56,69 \pm 6,63$	ND
<b>Diagnosis</b>			
ovarian cancer	5	2	
endometrial cancer	12	12	
cervical cancer	3	6	
Type of surgery	Robotic surgery	Robotic surgery	
Length of Surgery (h)	$3,37 \pm 1,27$	$3,42 \pm 088$	ND
<b>Comorbidity</b>			
arterial hypertension	8	8	
atrial fibrillation	1	1	
allergy	1	NP	
diabete mellitus	2	5	
hypothyroidism	2	NP	

Standard Ventilation (SV), Protective Ventilation (PV).

\* Data are presented as mean  $\pm$  standard deviation, ND: no statistical differences, NP: not presented.

baseline values at the end of the procedure (Fig. 3).

In both groups, no significant differences in terms of respiratory system resistances (Rmin and Rmax) were detected, although a not statistically significant increase of their values was observed after the

**Table 2**  
Respiratory mechanics parameters.

Baseline	Standard Ventilation Group	Protective Ventilation Group	p-value
Compliance (ml/cmH <sub>2</sub> O)	67,40 ± 2148	6571 ± 20,47	ND
Maximal Resistance (cmH <sub>2</sub> O/L/sec)	1421 ± 4,09	12,36 ± 3,95	ND
Minimal Resistance (cmH <sub>2</sub> O/L/sec)	838 ± 2,47	6,78 ± 3,68	ND
Delta Resistance (cmH <sub>2</sub> O/L/sec)	584 ± 2,89	5,59 ± 3,11	ND
After Pneumoperitoneum	Standard Ventilation Group	Protective Ventilation Group	p-value
Compliance (ml/cmH <sub>2</sub> O)	3558 ± 8,02	35,44 ± 8,45	ND
Maximal Resistance (cmH <sub>2</sub> O/L/sec)	1704 ± 5,11	15,12 ± 3,82	ND
Minimal Resistance (cmH <sub>2</sub> O/L/sec)	774 ± 3,02	6,95 ± 3,02	ND
Delta Resistance (cmH <sub>2</sub> O/L/sec)	931 ± 5,54	8,17 ± 4,22	ND
1h	Standard Ventilation Group	Protective Ventilation Group	p-value
Compliance (ml/cmH <sub>2</sub> O)	3653 ± 11,72	33,57 ± 7,14	ND
Maximal Resistance (cmH <sub>2</sub> O/L/sec)	1499 ± 6,29	13,41 ± 6,12	ND
Minimal Resistance (cmH <sub>2</sub> O/L/sec)	736 ± 3,19	5,89 ± 5,59	ND
Delta Resistance (cmH <sub>2</sub> O/L/sec)	763 ± 5,67	7,53 ± 4,50	ND
2h	Standard Ventilation Group	Protective Ventilation Group	p-value
Compliance (ml/cmH <sub>2</sub> O)	3691 ± 11,59	32,92 ± 6,29	ND
Maximal Resistance (cmH <sub>2</sub> O/L/sec)	1499 ± 4,96	14,32 ± 3,98	ND
Minimal Resistance (cmH <sub>2</sub> O/L/sec)	758 ± 337	7,44 ± 3,24	ND
Delta Resistance (cmH <sub>2</sub> O/L/sec)	741 ± 3,87	6,88 ± 3,38	ND
Post-extubation	Standard Ventilation Group	Protective Ventilation Group	p-value
Compliance (ml/cmH <sub>2</sub> O)	5714 ± 1532	5148 ± 950	ND
Maximal Resistance (cmH <sub>2</sub> O/L/sec)	1252 ± 3,94	11,73 ± 2,67	ND
Minimal Resistance (cmH <sub>2</sub> O/L/sec)	741 ± 2,22	7,55 ± 1,89	ND
Delta Resistance (cmH <sub>2</sub> O/L/sec)	511 ± 3,73	4,19 ± 243	ND

ND: no statistical differences.

start of pneumoperitoneum.

In both ventilation strategies, a significant reduction of pH from baseline to Ext time ( $p < 001$ ) was showed. At AP2, the decrease of pH values was significantly higher in the PV group compared to the SV group (SV  $743 \pm 004$  vs PV  $740 \pm 004$  at 2h,  $p < 0,01$ ). Significantly higher PaCO<sub>2</sub> values in PV group than in SV group were detected from AP1 to Ext time. Moreover, only the PV group showed a

significant increase of PaCO<sub>2</sub> values from BS to Ext time ( $p < 001$ ) (Table 3).

No significant differences were observed in terms of post-operative respiratory adverse events (30% in SV group vs 25% in PV group, respectively).

In terms of Hospital Length of Stay (HLOS), no difference was observed in both groups (SV:  $455 \pm 195$  vs PV:  $475 \pm 155$  days, respectively). Only one patient, in SV group, was admitted in Post-Operative Intensive Care Unit after procedure for a prolonged surgical treatment.

#### 4. Discussion

Our data showed that in patients with normal respiratory function submitted to robotic surgery in Deep Trendelenburg position under general anesthesia, the application of protective ventilation with RMs did not seem to positively affect the respiratory mechanics, compared to standard ventilation.

Similarly, higher PEEP and RMs did not improve intra and post-operative gas exchanges, neither modified the rate of post-operative pulmonary complications, compared to standard ventilation.

During general anesthesia, reduction of end-expiratory lung volumes and increase of airway closure pressures are commonly observed (Wirth et al., 2017). These two mechanisms contribute to atelectasis formation, the most important morbid post-operative pulmonary complication, that determines an increase of the risk for pneumonia and hypoxic acute respiratory failure (Arozullah et al., 2000; Smetana et al., 2006; Pelosi and Rocco, 2007; Wirth et al., 2017).

During laparoscopic procedures, the use of pneumoperitoneum and deep Trendelenburg position can cause additional deleterious changes in the pulmonary mechanics, such as: cephalad displacement of the diaphragm, decrease of Functional Residual Capacity (FRC) and static compliances, increase of airway pressures. In absence of corresponding adaptations of ventilatory parameters, a decrease of Vt and subsequently of minute ventilation may occur, leading to intrapulmonary shunting with consequent hypoxemia and hypercapnia (Fahy et al., 1995; Hedenstierna, Edmark, 2005).

Several ventilatory strategies aiming to improve arterial oxygenation and respiratory mechanics during laparoscopic surgery have been investigated. The application of PEEP has been shown to counterbalance the diaphragm cranial shift increasing FRC and increasing respiratory compliance (Pelosi et al., 1999; Perilli et al., 2000; Meininger et al., 2005; Maracajá-Neto et al., 2009; Talab et al., 2009). The concept of lung protective ventilation and “open lung” strategies used to treat Adult Respiratory Distress Syndrome (ARDS) (Rothen et al., 1993; Grasso et al., 2005; Chiumello et al., 2008; Talmor et al., 2008; Constantin et al., 2010) with the execution of RMs and the application of an adequate PEEP, has been suggested to effectively re-expand pneumoperitoneum-induced atelectasis and improve oxygenation during laparoscopic surgery (Whalen et al., 2006; Valenza et al., 2007; Cakmakkaya et al., 2009; Park et al., 2009; Futier et al., 2010).

Several studies evaluated the effects of “open lung strategy” and the positive effect of RMs and PEEP application during general anesthesia, especially during open abdominal surgery and in elderly patients. Severgnini et al., 2013 compared two ventilation strategies, Vt of 9 ml/kg and Zero PEEP versus Vt of 7 ml/kg and PEEP of 10 cmH<sub>2</sub>O with RMs application in open abdominal surgery. The authors showed that a protective ventilation strategy during anesthesia improved the post-operative respiratory function and reduced the rate of pulmonary infection during the first five post-operative days.

In their study, Weingarten et al., 2010 showed that an “open lung” strategy, performed in elderly patients undergoing open abdominal surgery, improved the intra-operative oxygenation and lung mechanics.

The PROVHILO trial (PROVE Network Investigation for the Clinical Trial Network of the European Society of Anesthesiology et al., 2014) was the first randomized controlled study powered to test the

### Respiratory System Compliance in Standard and Protective ventilation groups

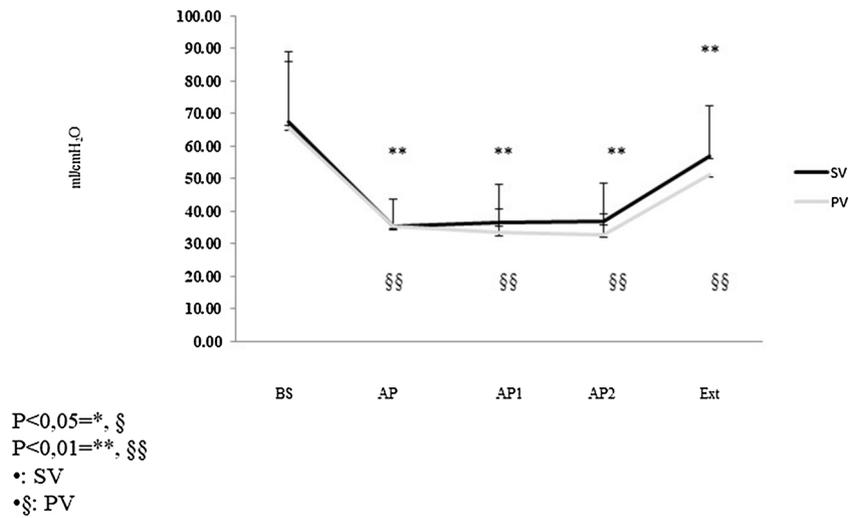


Fig. 2. Respiratory System Compliance trend in Standard Ventilation (black line) and Protective Ventilation (gray line) Groups during all phases of the study. BS: baseline, AP: after pneumoperitoneum, Ext: extubation time, p < 005 = \*, §; p < 0,01 = \*\*, §§.

### Airway Pressure Trends in Standard and Protective Ventilation groups

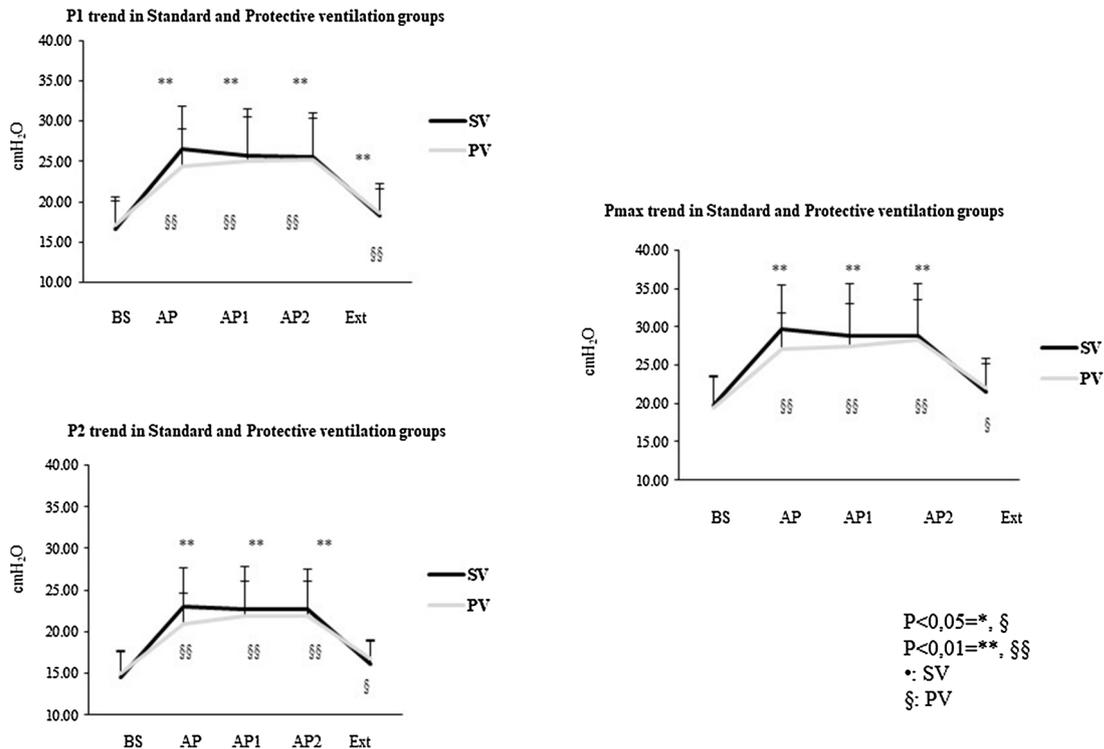


Fig. 3. Airway Pressures (P1, P2 and Pmax) trend in Standard Ventilation (black line) and Protective Ventilation (gray line) Groups during all phases of the study. BS: baseline, AP: after pneumoperitoneum, Ext: extubation time, p < 005 = \*, §; p < 0,01 = \*\*, §§.

hypothesis that an open lung mechanical ventilation strategy, with high levels of PEEP and RMs, during short-term intra-operative mechanical ventilation prevents post-operative pulmonary complications. In this study, 447 patients were randomly allocated to received high PEEP with RMs and 453 to low PEEP without RMs. In accordance to our results, during PROVHILO trial a strategy with high level of PEEP and RMs, during open abdominal surgery, did not protect against post-operative pulmonary complications.

Our data confirmed that Pneumoperitoneum and Trendelenburg

position cause a worsening of respiratory mechanics, mainly characterized by a decrease of static compliance and the consequent increase of pulmonary pressure. At the end of the surgical phase, in our experience and in accordance with the study of Wirth et al., 2017, when the pneumoperitoneum was stopped and patients returned to standard supine position, the respiratory mechanics (especially Static Compliance) did not fully recover.

The application of a protective ventilation in healthy patients during short term robotic surgery did not prevent the negative effects

**Table 3**  
Arterial blood gas.

Baseline	Standard Ventilation Group	Protective Ventilation Group	p-value
pH	7,48 ± 0,04	7,47 ± 0,04	ND
PaO <sub>2</sub> (mmHg)	19,558 ± 41,66	193,59 ± 40,30	ND
PaCO <sub>2</sub> (mmHg)	3220 ± 2,60	33,71 ± 389	ND
PaO <sub>2</sub> /FiO <sub>2</sub> ratio	488,95 ± 104,16	477,22 ± 91,45	ND
ETCO <sub>2</sub> (mmHg)	3355 ± 3,07	35,25 ± 3,73	ND
SpO <sub>2</sub> (%)	9805 ± 1,67	98,20 ± 170	ND
1h	Standard Ventilation Group	Protective Ventilation Group	p-value
pH	743 ± 0,03	741 ± 0,05	ND
PaO <sub>2</sub> (mmHg)	19,173 ± 34,49	188,13 ± 41,63	ND
PaCO <sub>2</sub> (mmHg)	3699 ± 3,59	40,67 ± 602	< 0,05
PaO <sub>2</sub> /FiO <sub>2</sub> ratio	480,43 ± 96,74	468,27 ± 109,83	ND
ETCO <sub>2</sub> (mmHg)	3885 ± 4,28	41,30 ± 4,32	ND
SpO <sub>2</sub> (%)	9860 ± 1,10	98,30 ± 1,03	ND
2h	Standard Ventilation Group	Protective Ventilation Group	p-value
pH	743 ± 0,04	740 ± 0,04	< 0,01
PaO <sub>2</sub> (mmHg)	19,641 ± 28,38	193,25 ± 30,38	ND
PaCO <sub>2</sub> (mmHg)	3770 ± 4,42	40,54 ± 390	< 0,01
PaO <sub>2</sub> /FiO <sub>2</sub> ratio	499,73 ± 91,50	481,66 ± 89,56	ND
ETCO <sub>2</sub> (mmHg)	3860 ± 4,48	41,70 ± 4,00	< 0,01
SpO <sub>2</sub> (%)	9885 ± 1,14	98,50 ± 0,83	ND
Pre-extubation	Standard Ventilation Group	Protective Ventilation Group	p-value
pH	743 ± 0,03	741 ± 0,04	ND
PaO <sub>2</sub> (mmHg)	19,595 ± 33,89	186,65 ± 40,12	ND
PaCO <sub>2</sub> (mmHg)	3670 ± 5,06	39,35 ± 526	< 0,01
PaO <sub>2</sub> /FiO <sub>2</sub> ratio	490,56 ± 95,00	466,63 ± 100,31	ND
ETCO <sub>2</sub> (mmHg)	3747 ± 5,67	39,75 ± 5,30	ND
SpO <sub>2</sub> (%)	9884 ± 1,26	98,55 ± 1,05	ND

PaO<sub>2</sub>: arterial oxygen partial pressure, PaCO<sub>2</sub>: arterial carbon dioxide partial pressure, ETCO<sub>2</sub>: End Tidal carbon dioxide, SpO<sub>2</sub>: oxygen peripheral saturation, ND: no statistical differences.

on respiratory mechanics due to pneumoperitoneum and deep Trendelenburg position. Unfortunately, our data did not suggest which specific ventilatory approach can improve Respiratory Mechanics and gas exchange in this particular surgical setting. Nevertheless, a bedside analysis of Respiratory Mechanics might be a desirable means to individualize the "best level of PEEP", the type of RMs and/or tidal volume requirements needed to improve the ventilatory approach. This approach should be desirable in high risk patients.

In our study we did not observe differences in terms of intra-operative oxygenation between the two groups. The increase of PaCO<sub>2</sub> and a decrease of pH during the intra-operative phase, especially in the PV group, were similar to those previously published in literature (Kuzkov et al., 2016). The tendency to a mild hypercapnia in PV group could be related to an increase of the dead space during protective ventilation strategy in a healthy lung, stressed by the deep Trendelenburg position, as well as the effect of a reduced alveolar ventilation related to a decrease of tidal volume. However, this mild respiratory acidosis did not affect post-operative gas exchange and pulmonary respiratory adverse events in PV group, and should be considered clinically irrelevant.

The study has some limitations: (1) this was a single-center study with a small sample size; (2) the patients enrolled were healthy women scheduled for elective laparoscopic surgery, therefore more studies are required to evaluate the effects of the open lung strategy on respiratory

mechanics in patients with coexisting cardiopulmonary diseases; (3) we did not use the esophageal balloon to measure the esophageal pressure and consequently transpulmonary pressure, because esophageal balloon displacements are frequent with the application of Deep Trendelenburg position (> 30°) and the execution of repeated RMs; 3) there was a limited follow-up due to the fast post-operative discharge from the hospital of the patients enrolled.

## 5. Conclusions

The present study shows that, during short term robotic surgery in Deep Trendelenburg position in patients with normal respiratory function, the application of a protective strategy does not guarantee any improvement in terms of respiratory mechanics, gas exchanges and rate of post-operative pulmonary complications. Further studies are needed to determine the respiratory effects of protective ventilation during Robotic surgery and Deep Trendelenburg position in patients with respiratory impairment related to pre-existing pulmonary disease or elevated BMI.

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