

Evita® Infinity® V500

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Literature List

Image-Guided Lung Protection

Recruitability, Protective Ventilation, PEEP setting,
Tidal Recruitment, VALI, ARDS, EIT ...

Image-guided lung protection

Literature List

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<p>Karsten J, et al.</p>	<p>Determination of optimal positive end-expiratory pressure based on respiratory compliance and electrical impedance tomography: a pilot clinical comparative trial</p>	<p>Biomed. Eng.-Biomed. Tech. 2018 Jun</p>
<p>Abstract: There is no agreement on gold standard method for positive end-expiratory pressure (PEEP) titration. Electrical impedance tomography (EIT) may aid in finding the optimal PEEP level. In this pilot trial, we investigated potential differences in the suggested optimal PEEP (<i>BestPEEP</i>) as derived by respiratory compliance and EIT-derived parameters. We examined if compliance-derived PEEP differs with regard to the regional ventilation distribution in relation to atelectasis and hyperinflation. Measurements were performed during an incremental/decremental PEEP trial in 15 ventilated intensive care patients suffering from mild-to-moderate impairment of oxygenation due to sepsis, pneumonia, trauma and metabolic and ischemic disorders. Measurement agreement was analyzed using Bland-Altman plots. We observed a diversity of EIT-derived and compliance-based optimal PEEP in the evaluated patients. <i>BestPEEP_{Compliance}</i> did not necessarily correspond to the <i>BestPEEP_{ODCL}</i> with the least regional overdistension and collapse. The collapsed area was significantly smaller when the overdistension/collapse index was used for PEEP definition (p=0.022). Our results showed a clinically relevant difference in the suggested optimal PEEP levels when using different parameters for PEEP titration. The compliance-derived PEEP level revealed a higher proportion of residual regional atelectasis as compared to EIT-based PEEP.</p>		
<p>Heines S J H, et al.</p>	<p>Clinical implementation of electric impedance tomography in the treatment of ARDS: a single centre experience</p>	<p>M.C.G. et al. J Clin Monit Comput 2018 May</p>
<p>Abstract: To report on our clinical experience using EIT in individualized PEEP titration in ARDS. Using EIT assessment, we optimized PEEP settings in 39 ARDS patients. The EIT PEEP settings were compared with the physicians' PEEP settings and the PEEP settings according to the ARDS network. We defined a PEEP difference equal to or greater than 4 cm H₂O as clinically relevant. Changes in lung compliance and PaO₂/FiO₂-ratio were compared in patients with EIT-based PEEP adjustments and in patients with unaltered PEEP. In 28% of the patients, the difference in EIT-based PEEP and physician-PEEP was clinically relevant; in 36%, EIT-based PEEP and physician-PEEP were equal. The EIT-based PEEP disagreed with the PEEP settings according to the ARDS network. Adjusting PEEP based upon EIT led to a rapid increase in lung compliance and PaO₂/FiO₂-ratio. However, this increase was also observed in the group where the PEEP difference was less than 4 cm H₂O. We hypothesize that this can be attributed to the alveolar recruitment during the PEEP trial. EIT based individual PEEP setting appears to be a promising method to optimize PEEP in ARDS patients. The clinical impact, however, remains to be established.</p>		

<p>Nestler C, et al.</p>	<p>Individualized positive end-expiratory pressure in obese patients during general anaesthesia: a randomized controlled clinical trial using electrical impedance tomography.</p>	<p>Br J Anaesth. 2017 Dec</p>
<p>Background: General anaesthesia leads to atelectasis, reduced end-expiratory lung volume (EELV), and diminished arterial oxygenation in obese patients. We hypothesized that a combination of a recruitment manoeuvre (RM) and individualized positive end-expiratory pressure (PEEP) can avoid these effects.</p> <p>Methods: Patients with a BMI ≥ 35 kg m⁻² undergoing elective laparoscopic surgery were randomly allocated to mechanical ventilation with a tidal volume of 8 ml kg⁻¹ predicted body weight and (i) an RM followed by individualized PEEP titrated using electrical impedance tomography (PEEP_{IND}) or (ii) no RM and PEEP of 5 cm H₂O (PEEP₅). Gas exchange, regional ventilation distribution, and EELV (multiple breath nitrogen washout method) were determined before, during, and after anaesthesia. The primary end point was the ratio of arterial partial pressure of oxygen to inspiratory oxygen fraction (PaO₂/FiO₂).</p> <p>Results: For PEEP_{IND} (n =25) and PEEP₅ (n =25) arms together, PaO₂/FiO₂ and EELV decreased by 15 kPa [95% confidence interval (CI) 11-20 kPa, P <0.001] and 1.2 litres (95% CI 0.9-1.6 litres, P <0.001), respectively, after intubation. Mean (sd) PEEP_{IND} was 18.5 (5.6) cm H₂O. In the PEEP_{IND} arm, PaO₂/FiO₂ before extubation was 23 kPa higher (95% CI 16-29 kPa; P <0.001), EELV was 1.8 litres larger (95% CI 1.5-2.2 litres; P <0.001), driving pressure was 6.7 cm H₂O lower (95% CI 5.4-7.9 cm H₂O; P <0.001), and regional ventilation was more equally distributed than for PEEP₅. After extubation, however, these differences between the arms vanished.</p> <p>Conclusions: In obese patients, an RM and higher PEEP IND restored EELV, regional ventilation distribution, and oxygenation during anaesthesia, but these differences did not persist after extubation. Therefore, lung protection strategies should include the postoperative period.</p>		
<p>Amado-Rodríguez L, et al.</p>	<p>Mechanical ventilation in acute respiratory distress syndrome: The open lung revisited</p>	<p>Med Intensiva. 2017 Dec</p>
<p>Abstract: Acute respiratory distress syndrome (ARDS) is still related to high mortality and morbidity rates. Most patients with ARDS will require ventilatory support. This treatment has a direct impact upon patient outcome and is associated to major side effects. In this regard, ventilator-associated lung injury (VALI) is the main concern when this technique is used. The ultimate mechanisms of VALI and its management are under constant evolution. The present review describes the classical mechanisms of VALI and how they have evolved with recent findings from physiopathological and clinical studies, with the aim of analyzing the clinical implications derived from them. Lastly, a series of knowledge-based recommendations are proposed that can be helpful for the ventilator assisted management of ARDS at the patient bedside.</p>		
<p>Li HL, et al.</p>	<p>Protecting lungs during spontaneous breathing: what can we do?</p>	<p>J Thorac Dis 2017 Sep</p>
<p><i>Comment on: Yoshida T, Nakahashi S, Nakamura MA, et al. Volume Controlled Ventilation Does Not Prevent Injurious Inflation During Spontaneous Effort. Am J Respir Crit Care Med 2017</i></p> <p>Conclusions: Yoshida's study advanced our understanding on regional respiratory mechanics during spontaneous breathing. The main result denied the hypothesis that volume controlled ventilation would safely prevent lungs from P-SILI. Moreover, conventional parameters including tidal volume, driving pressure or even esophageal pressure may underestimate the regional stress at dependent lung. This makes the assessment of the risk of P-SILI more challenging in clinical practice. Nevertheless, one should bear in mind that what Yoshida tested is a specified volume control ventilation with a relatively low preset flow (<30 L/min) and a low PEEP (3–10 cmH₂O). The door of optimizing ventilator settings and modes to reduce P-SILI remains open. Back to a physiology standpoint, seeking for a ventilatory strategy to minimize P-SILI with preserved spontaneous effort should not and will not stop.</p>		

Franchineau G, et al.	Bedside Contribution of Electrical Impedance Tomography to Set Positive End-Expiratory Pressure for ECMO-Treated Severe ARDS Patients	<i>J Crit Care</i> <u>2017 Aug</u>
<p>Rationale: Optimal positive end-expiratory pressure (PEEP) is unknown in patients with severe acute respiratory distress syndrome (ARDS) on extracorporeal membrane oxygenation receiving mechanical ventilation with very low tidal volume.</p> <p>Objectives: To evaluate the ability of electrical impedance tomography (EIT) to monitor a PEEP trial and to derive from EIT the best compromise PEEP in this setting.</p> <p>Methods: A decremental PEEP trial (20-0 cm H₂O) in 5 cm H₂O steps was monitored by EIT, with lung images divided into four ventral-to-dorsal horizontal regions of interest. The EIT-based PEEP providing the best compromise between overdistention and collapsed zones was arbitrarily defined as the lowest pressure able to limit EIT-assessed collapse to less than or equal to 15% with the least overdistention. Driving pressure was maintained constant at 14 cm H₂O in pressure controlled mode.</p> <p>Measurements and main results: Tidal volume, static compliance, tidal impedance variation, end-expiratory lung impedance, and their respective regional distributions were visualized at each PEEP level in 15 patients on extracorporeal membrane oxygenation. Low tidal volume (2.9-4 ml/kg ideal body weight) and poor compliance (12.1-18.7 ml/cm H₂O) were noted, with significantly higher tidal volume and compliance at PEEP₁₀ and PEEP₅ than PEEP₂₀. EIT-based best compromise PEEPs were 15, 10, and 5 cm H₂O for seven, six, and two patients, respectively, whereas PEEP₂₀ and PEEP₀ were never selected.</p> <p>Conclusions: The broad variability in optimal PEEP observed in these patients with severe ARDS under extracorporeal membrane oxygenation reinforces the need for personalized titration of ventilation settings. EIT may be an interesting noninvasive bedside tool to provide real-time monitoring of the PEEP impact in these patients.</p>		

Eronia N et al.	Bedside selection of positive end-expiratory pressure by electrical impedance tomography in hypoxemic patients: a feasibility study	<i>Ann. Intensive Care</i> <u>2017 Jul</u>
<p>Background: Positive end-expiratory pressure (PEEP) is a key element of mechanical ventilation. It should optimize recruitment, without causing excessive overdistension, but controversy exists on the best method to set it. The purpose of the study was to test the feasibility of setting PEEP with electrical impedance tomography in order to prevent lung de-recruitment following a recruitment maneuver. We enrolled 16 patients undergoing mechanical ventilation with PaO₂/FiO₂ <300 mmHg. In all patients, under constant tidal volume (6–8 ml/kg) PEEP was set based on the PEEP/FiO₂ table proposed by the ARDS network (PEEP_{ARDSnet}). We performed a recruitment maneuver and monitored the end-expiratory lung impedance (EELI) over 10 min. If the EELI signal decreased during this period, the recruitment maneuver was repeated and PEEP increased by 2 cmH₂O. This procedure was repeated until the EELI maintained a stability over time (PEEP_{EIT}).</p> <p>Results: The procedure was feasible in 87% patients. PEEP_{EIT} was higher than PEEP_{ARDSnet} (13 ± 3 vs. 9 ± 2 cmH₂O, p < 0.001). PaO₂/FiO₂ improved during PEEP_{EIT} and driving pressure decreased. Recruited volume correlated with the decrease in driving pressure but not with oxygenation improvement. Finally, regional alveolar hyperdistention and collapse was reduced in dependent lung layers and increased in non-dependent lung layers.</p> <p>Conclusions: In hypoxemic patients, a PEEP selection strategy aimed at stabilizing alveolar recruitment guided by EIT at the bedside was feasible and safe. This strategy led, in comparison with the ARDSnet table, to higher PEEP, improved oxygenation and reduced driving pressure, allowing to estimate the relative weight of overdistension and recruitment.</p>		

<p>Mauri T, et al.</p>	<p>Bedside assessment of the effects of positive end-expiratory pressure on lung inflation and recruitment by the helium dilution technique and electrical impedance tomography.</p>	<p><i>Intensive Care Med.</i> 2016 Oct</p>
<p>Abstract: Higher positive end-expiratory pressure might induce lung inflation and recruitment, yielding enhanced regional lung protection. We measured positive end-expiratory pressure-related lung volume changes by electrical impedance tomography and by the helium dilution technique. We also used electrical impedance tomography to assess the effects of positive end-expiratory pressure on regional determinants of ventilator-induced lung injury.</p> <p>Methods: A prospective randomized crossover study was performed on 20 intubated adult patients: 12 with acute hypoxemic respiratory failure and 8 with acute respiratory distress syndrome. Each patient underwent protective controlled ventilation at lower (7 [7, 8] cmH₂O) and higher (12 [12, 13] cmH₂O) positive end-expiratory pressures. At the end of each phase, we collected ventilation, helium dilution, and electrical impedance tomography data.</p> <p>Results: Positive end-expiratory pressure-induced changes in lung inflation and recruitment measured by electrical impedance tomography and helium dilution showed close correlations ($R^2 = 0.78$, $p < 0.001$ and $R^2 = 0.68$, $p < 0.001$, respectively) but with relatively variable limits of agreement. At higher positive end-expiratory pressure, recruitment was evident in all lung regions ($p < 0.01$) and heterogeneity of tidal ventilation distribution was reduced by increased tidal volume distending the dependent lung ($p < 0.001$); in the non-dependent lung, on the other hand, compliance decreased ($p < 0.001$) and tidal hyperinflation significantly increased ($p < 0.001$). In the subgroup of ARDS patients (but not in the whole study population) tidal hyperinflation in the dependent lung regions decreased at higher positive end-expiratory pressure ($p = 0.05$), probably indicating higher potential for recruitment.</p> <p>Conclusions: Close correlations exist between bedside assessment of positive end-expiratory pressure-induced changes in lung inflation and recruitment by the helium dilution and electrical impedance tomography techniques. Higher positive end-expiratory pressure exerts mixed effects on the regional determinants of ventilator-induced lung injury; these merit close monitoring.</p>		
<p>Spaeth J, et al.</p>	<p>Increasing positive end-expiratory pressure (re-)improves intraoperative respiratory mechanics and lung ventilation after prone positioning.</p>	<p><i>Br J Anaesth.</i> 2016 Jun</p>
<p>Background: Turning a patient prone, changes the respiratory mechanics and potentially the level of positive end-expiratory pressure (PEEP) that is necessary to prevent alveolar collapse. In this prospective clinical study we examined the impact of PEEP on the intratidal respiratory mechanics and regional lung aeration in the prone position. We hypothesized that a higher PEEP is required to maintain compliance and regional ventilation in the prone position.</p> <p>Methods: After ethical approval, 45 patients with healthy lungs undergoing lumbar spine surgery were examined in the supine position at PEEP 6 cm H₂O and in the prone position at PEEP (6, 9 and 12 cm H₂O). Dynamic compliance (CRS) and intratidal compliance-volume curves were determined and regional ventilation was measured using electrical impedance tomography. The compliance-volume curves were classified to indicate intratidal derecruitment, overdistension, or neither.</p> <p>Results: CRS did not differ between postures and PEEP levels ($P > 0.28$). At a PEEP of 6 cm H₂O a compliance-volume profile indicating neither derecruitment nor overdistension was observed in 38 supine, but only in 20 prone positioned patients ($P < 0.001$). The latter increased to 33 and 37 (both $P < 0.001$) when increasing PEEP to 9 and 12 cm H₂O, respectively. Increasing PEEP from 6 to 9 cm H₂O in the prone position increased peripheral ventilation significantly.</p> <p>Conclusions: Respiratory system mechanics change substantially between supine and prone posture, which is not demonstrated in routine measurements. The intratidal compliance analysis suggests that in most patients a PEEP above commonly used settings is necessary to avoid alveolar collapse in the prone position.</p>		

<p>Blankman P, et al.</p>	<p>Detection of optimal PEEP for equal distribution of tidal volume by volumetric capnography and electrical impedance tomography during decreasing levels of PEEP in post cardiac-surgery patients</p>	<p>Br J Anaesth. 2016 Jun</p>
<p>Background: Homogeneous ventilation is important for prevention of ventilator-induced lung injury. Electrical impedance tomography (EIT) has been used to identify optimal PEEP by detection of homogenous ventilation in non-dependent and dependent lung regions. We aimed to compare the ability of volumetric capnography and EIT in detecting homogenous ventilation between these lung regions.</p> <p>Methods: Fifteen mechanically-ventilated patients after cardiac surgery were studied. Ventilator settings were adjusted to volume-controlled mode with a fixed tidal volume (Vt) of 6–8ml kg⁻¹ predicted body weight. Different PEEP levels were applied (14 to 0 cm H₂O, in steps of 2 cm H₂O) and blood gases, Vcap and EIT were measured.</p> <p>Results: Tidal impedance variation of the non-dependent region was highest at 6 cm H₂O PEEP, and decreased significantly at 14 cm H₂O PEEP indicating decrease in the fraction of Vt in this region. At 12 cm H₂O PEEP, homogenous ventilation was seen between both lung regions. Bohr and Enghoff dead space calculations decreased from a PEEP of 10 cm H₂O. Alveolar dead space divided by alveolar Vt decreased at PEEP levels ≤6 cm H₂O. The normalized slope of phase III significantly changed at PEEP levels ≤4 cm H₂O. Airway dead space was higher at higher PEEP levels and decreased at the lower PEEP levels.</p> <p>Conclusions: In postoperative cardiac patients, calculated dead space agreed well with EIT to detect the optimal PEEP for an equal distribution of inspired volume, amongst non-dependent and dependent lung regions. Airway dead space reduces at decreasing PEEP levels.</p>		
<p>He X, et al.</p>	<p>Electrical Impedance Tomography-guided PEEP Titration in Patients Undergoing Laparoscopic Abdominal Surgery.</p>	<p>Medicine (Baltimore) 2016 Apr</p>
<p>Abstract:</p> <p>The aim of the study is to utilize electrical impedance tomography (EIT) to guide positive end-expiratory pressure (PEEP) and to optimize oxygenation in patients undergoing laparoscopic abdominal surgery. Fifty patients were randomly assigned to the control (C) group and the EIT (E) group (n=25 each). We set the fraction of inspired oxygen (FiO₂) at 0.30. The PEEP was titrated and increased in a 2-cm H₂O stepwise manner, from 6 to 14cm H₂O. Hemodynamic variables, respiratory mechanics, EIT images, analysis of blood gas, and regional cerebral oxygen saturation were recorded. The postoperative pulmonary complications within the first 5 days were also observed. We chose 10cm H₂O and 8cm H₂O as the "ideal" PEEP for the C and the E groups, respectively. EIT-guided PEEP titration led to a more dorsal shift of ventilation. The PaO₂/FiO₂ ratio in the E group was superior to that in the C group in the pneumoperitoneum period, though the difference was not significant (330±10 vs 305.56±4mm Hg; P=0.09). The C group patients experienced 8.7% postoperative pulmonary complications versus 5.3% among the E group patients (relative risk 1.27, 95% confidence interval 0.31-5.3, P=0.75).Electrical impedance tomography represents a new promising technique that could enable anesthesiologists to assess regional ventilation of the lungs and optimize global oxygenation for patients undergoing laparoscopic abdominal surgery.</p>		

<p>Hsu CF, et al.</p>	<p>Electrical impedance tomography monitoring in acute respiratory distress syndrome patients with mechanical ventilation during prolonged positive end-expiratory pressure adjustments</p>	<p><i>J Formos Med Assoc.</i> 2016 Mar</p>
<p>Background: The time required to reach oxygenation equilibrium after positive end-expiratory pressure (PEEP) adjustments in mechanically ventilated patients with acute respiratory distress syndrome (ARDS) is unclear. We used electrical impedance tomography to elucidate gas distribution and factors related to oxygenation status following PEEP in patients with ARDS.</p> <p>Methods: Nineteen mechanically ventilated ARDS patients were placed on baseline PEEP (PEEP_B) for 1 hour, PEEP_B - 4 cmH₂O PEEP (PEEP_L) for 30 minutes, and PEEP_B + 4 cmH₂O PEEP (PEEP_H) for 1 hour. Tidal volume and respiratory rate were similar. Impedance changes, respiratory parameters, and arterial blood gases were measured at baseline, 5 minutes, and 30 minutes after PEEP_L, and 5 minutes, 15 minutes, 30 minutes, and 1 hour after PEEP_H.</p> <p>Results: PaO₂/fraction of inspired oxygen (P/F ratio) decreased quickly from PEEP_B to PEEP_L, and stabilized 5 minutes after PEEP_L. However the P/F ratio progressively increased from PEEP_L to PEEP_H, and a significantly higher P/F ratio and end-expiratory lung impedance were found at 60 minutes compared to 5 minutes after PEEP_H. The end-expiratory lung impedance level significantly correlated with P/F ratio ($p < 0.001$). With increasing PEEP, dorsal ventilation significantly increased; however, regional ventilation did not change over time with PEEP level.</p> <p>Conclusions: Late improvements in oxygenation following PEEP escalation are probably due to slow recruitment in ventilated ARDS patients. Electrical impedance tomography may be an appropriate tool to assess recruitment and oxygenation status in patients with changes in PEEP.</p>		
<p>Bellani G, et al.</p>	<p>Epidemiology, Patterns of Care, and Mortality for Patients With Acute Respiratory Distress Syndrome in Intensive Care Units in 50 Countries.</p>	<p><i>JAMA.</i> 2016 Feb</p>
<p>Importance: Limited information exists about the epidemiology, recognition, management, and outcomes of patients with the acute respiratory distress syndrome (ARDS).</p> <p>Objectives: To evaluate intensive care unit (ICU) incidence and outcome of ARDS and to assess clinician recognition, ventilation management, and use of adjuncts - for example prone positioning - in routine clinical practice for patients fulfilling the ARDS Berlin Definition.</p> <p>Design, setting and participants: The Large Observational Study to Understand the Global Impact of Severe Acute Respiratory Failure (LUNG SAFE) was an international, multicenter, prospective cohort study of patients undergoing invasive or noninvasive ventilation, conducted during 4 consecutive weeks in the winter of 2014 in a convenience sample of 459 ICUs from 50 countries across 5 continents.</p> <p>Exposures: Acute respiratory distress syndrome.</p> <p>Main outcomes and measures: The primary outcome was ICU incidence of ARDS. Secondary outcomes included assessment of clinician recognition of ARDS, the application of ventilatory management, the use of adjunctive interventions in routine clinical practice, and clinical outcomes from ARDS.</p> <p>Results: Of 29,144 patients admitted to participating ICUs, 3022 (10.4%) fulfilled ARDS criteria. Of these, 2377 patients developed ARDS in the first 48 hours and whose respiratory failure was managed with invasive mechanical ventilation. The period prevalence of mild ARDS was 30.0% (95% CI, 28.2%-31.9%); of moderate ARDS, 46.6% (95% CI, 44.5%-48.6%); and of severe ARDS, 23.4% (95% CI, 21.7%-25.2%). ARDS represented 0.42 cases per ICU bed over 4 weeks and represented 10.4% (95% CI, 10.0%-10.7%) of ICU admissions and 23.4% of patients requiring mechanical ventilation.</p>		

Clinical recognition of ARDS ranged from 51.3% (95% CI, 47.5%-55.0%) in mild to 78.5% (95% CI, 74.8%-81.8%) in severe ARDS. Less than two-thirds of patients with ARDS received a tidal volume 8 of mL/kg or less of predicted body weight. Plateau pressure was measured in 40.1% (95% CI, 38.2-42.1), whereas 82.6% (95% CI, 81.0%-84.1%) received a positive end-expiratory pressure (PEEP) of less than 12 cm H₂O. Prone positioning was used in 16.3% (95% CI, 13.7%-19.2%) of patients with severe ARDS. Clinician recognition of ARDS was associated with higher PEEP, greater use of neuromuscular blockade, and prone positioning. Hospital mortality was 34.9% (95% CI, 31.4%-38.5%) for those with mild, 40.3% (95% CI, 37.4%-43.3%) for those with moderate, and 46.1% (95% CI, 41.9%-50.4%) for those with severe ARDS.

Conclusion and relevance: Among ICUs in 50 countries, the period prevalence of ARDS was 10.4% of ICU admissions. This syndrome appeared to be underrecognized and undertreated and associated with a high mortality rate. These findings indicate the potential for improvement in the management of patients with ARDS.

Godet T, et al.

[How to monitor a recruitment maneuver at the bedside.](#)

[Curr Opin Crit Care. 2015 Jun](#)

Purpose of review: To provide an overview on most recent knowledge on methods currently available for monitoring of recruitment maneuvers at the bedside.

Recent findings: The effects of recruitment maneuvers on clinical outcomes in patients with moderate to severe acute respiratory distress syndrome and in patients with healthy lungs undergoing major surgery were recently assessed. Despite being part of a multifaceted approach of protective ventilation, recruitment maneuvers are supposed to decrease mortality and improve postoperative outcomes. However, the role of recruitment maneuver remains controversial in routine practice owing to concerns regarding complications, especially its effects on hemodynamics. In addition, although recruitment maneuvers are being increasingly used, there remains a great deal of uncertainty regarding the precise way to evaluate the effect of recruitment.

An effective recruitment maneuver is expected to reinflate nonaerated lung units. End-expiratory lung volume, compliance, dead space, volumetric capnography, and bedside imaging techniques such as lung ultrasound and electrical impedance tomography have all different strengths and weaknesses. A multimodal and multiparametric approach could be a valuable option for bedside monitoring of recruitment maneuvers both in the ICU and in the operative room.

Summary: Several methods offer evaluation of lung recruitability and allow the monitoring of positive and negative effects of recruitment maneuvers. More than the type of method used, a multifaceted approach of monitoring of recruitment maneuvers should be regarded.

<p>Long Y, et al.</p>	<p>Positive End-expiratory Pressure Titration after Alveolar Recruitment Directed by Electrical Impedance Tomography</p>	<p><i>Chin Med J (Engl)</i> <i>2015 Jun</i></p>
<p>Background: Electrical impedance tomography (EIT) is a real-time bedside monitoring tool, which can reflect dynamic regional lung ventilation. The aim of the present study was to monitor regional gas distribution in patients with acute respiratory distress syndrome (ARDS) during positive-end-expiratory pressure (PEEP) titration using EIT.</p> <p>Methods: Eighteen ARDS patients under mechanical ventilation in Department of Critical Care Medicine of Peking Union Medical College Hospital from January to April in 2014 were included in this prospective observational study. After recruitment maneuvers (RMs), decremental PEEP titration was performed from 20 cmH₂O to 5 cmH₂O in steps of 3 cmH₂O every 5-10 min. Regional overdistension and recruitment were monitored with EIT.</p> <p>Results: After RMs, patient with arterial blood oxygen partial pressure (PaO₂) + carbon dioxide partial pressure (PaCO₂) >400 mmHg with 100% of fractional inspired oxygen concentration were defined as RM responders. Thirteen ARDS patients was diagnosed as responders whose PaO₂ + PaCO₂ were higher than nonresponders (419 ± 44 mmHg vs. 170 ± 73 mmHg, P < 0.0001). In responders, PEEP mainly increased recruited pixels in dependent regions and over-distended pixels in nondependent regions. PEEP alleviated global inhomogeneity of tidal volume and end-expiratory lung volume. PEEP levels without significant alveolar derecruitment and over-distension were identified individually.</p> <p>Conclusions: After RMs, PEEP titration significantly affected regional gas distribution in lung, which could be monitored with EIT. EIT has the potential to optimize PEEP titration.</p>		
<p>Karsten J, et al.</p>	<p>Positive end-expiratory pressure titration at bedside using electrical impedance tomography in post-operative cardiac surgery patients.</p>	<p><i>Acta Anaesthesiol Scand</i> <i>2015 Jul</i></p>
<p>Background: Post-operative positive end-expiratory pressure (PEEP) setting to minimize the risk of ventilator-associated lung injury is still controversial. Assessment of regional ventilation distribution by electrical impedance tomography (EIT) might be superior as compared with global parameters. The aim of this prospective observational study was to compare global dynamic compliance (CRS) with different EIT indices during a short clinical applicable descending PEEP trial.</p> <p>Methods: Twenty mechanically ventilated patients after elective cardiac surgery received a standard recruitment manoeuvre (RM) following descending PEEP trial in steps of 2 cmH₂O from PEEP 14 cmH₂O to 6 cmH₂O. During baseline and all PEEP steps, CRS was assessed and regional ventilation distribution was measured by means of EIT. The individual 'best' PEEP values for the derived EIT indices and CRS were calculated and compared.</p> <p>Results: The descending PEEP trial lasted less than 10 min. CRS increased after the RM and showed a maximum value at PEEP 8 cmH₂O. Ventilation distribution shifted more to dependent lung regions after RM and back to more non-dependent regions during the PEEP trial. Individual 'best' PEEP by CRS showed significantly lower values than 'best' PEEP by ventilation distribution measured with EIT indices.</p> <p>Conclusions: During a short descending PEEP trial at bedside, EIT is capable of following the status of regional ventilation distribution in ventilated patients. The 'best' PEEP value identified by individual maximum CRS was lower than optimal PEEP levels as determined by means of EIT indices. EIT could help setting PEEP in post-operative ventilated patients.</p>		

<p>Cressoni M, et al.</p>	<p>Lung Inhomogeneity in Patients with Acute Respiratory Distress Syndrome</p>	<p><i>Am J Respir Crit Care Med.</i> 2014 Jan</p>
<p>Abstract: Rationale: Pressures and volumes needed to induce ventilator-induced lung injury in healthy lungs are far greater than those applied in diseased lungs. A possible explanation may be the presence of local inhomogeneities acting as pressure multipliers (stress raisers).</p> <p>Objectives: To quantify lung inhomogeneities in patients with acute respiratory distress syndrome (ARDS).</p> <p>Methods: Retrospective quantitative analysis of CT scan images of 148 patients with ARDS and 100 control subjects. An ideally homogeneous lung would have the same expansion in all regions; lung expansion was measured by CT scan as gas/tissue ratio and lung inhomogeneities were measured as lung regions with lower gas/tissue ratio than their neighboring lung regions. We defined as the extent of lung inhomogeneities the fraction of the lung showing an inflation ratio greater than 95th percentile of the control group (1.61).</p> <p>Measurements and Main Results: The extent of lung inhomogeneities increased with the severity of ARDS (14 ± 5, 18 ± 8, and $23 \pm 10\%$ of lung volume in mild, moderate, and severe ARDS; $P < 0.001$) and correlated with the physiologic dead space ($r^2 = 0.34$; $P < 0.0001$). The application of positive end-expiratory pressure reduced the extent of lung inhomogeneities from 18 ± 8 to $12 \pm 7\%$ ($P < 0.0001$) going from 5 to 45 cm H₂O airway pressure. Lung inhomogeneities were greater in nonsurvivor patients than in survivor patients (20 ± 9 vs. $17 \pm 7\%$ of lung volume; $P = 0.01$) and were the only CT scan variable independently associated with mortality at backward logistic regression.</p> <p>Conclusions: Lung inhomogeneities are associated with overall disease severity and mortality. Increasing the airway pressures decreased but did not abolish the extent of lung inhomogeneities.</p>		
<p>Guerin C, et al.</p>	<p>Efficacy and safety of recruitment maneuvers in acute respiratory distress syndrome</p>	<p><i>Ann Intensive Care.</i> 2011 Apr</p>
<p>Abstract: Recruitment maneuvers (RM) consist of a ventilatory strategy that increases the transpulmonary pressure transiently to reopen the recruitable lung units in acute respiratory distress syndrome (ARDS). The rationales to use RM in ARDS are that there is a massive loss of aerated lung and that once the end-inspiratory pressure surpasses the regional critical opening pressure of the lung units, those units are likely to reopen. There are different methods to perform RM when using the conventional ICU ventilator. The three RM methods that are mostly used and investigated are sighs, sustained inflation, and extended sigh. There is no standardization of any of the above RM. Meta-analysis recommended not to use RM in routine in stable ARDS patients but to run them in case of life-threatening hypoxemia. There are some concerns regarding the safety of RM in terms of hemodynamics preservation and lung injury as well. The rapid rising in pressure can be a factor that explains the potential harmful effects of the RM. In this review, we describe the balance between the beneficial effects and the harmful consequences of RM. Recent animal studies are discussed.</p>		
<p>Okamoto VN, et al.</p>	<p>Recruitment Maneuvers in ARDS</p>	<p><i>Springer: Slutsky A.S., Brochard L. (eds) Mechanical Ventilation</i> 2005</p>
<p>Introduction: After a decade of evolving concepts about mechanical ventilation in patients with acute lung injury (ALI) and acute respiratory distress syndrome (ARDS), it is now indisputable that reducing lung stretch by limiting the end-inspiratory lung volume powerfully impacts on the outcome of such patients [1, 2]. However, uncertainty remains concerning the relative role of the maintenance of the end-expiratory volume in the context of ALI/ARDS. The avoidance of lung collapse and cyclic reopening may probably determine further benefit on patient outcome but it is a much more complex hypothesis to be tested in randomized clinical trials than the simple reduction of lung stretch [3]. In this chapter, we review the evidence that air space collapse is a major feature of ALI/ARDS and that the presence of lung collapse, either persistent or cyclic, is detrimental. We also comment on the difficulties involved in the testing of a comprehensive protective strategy in the clinical arena.</p>		

<p>Grasso S, et al.</p>	<p>Effects of recruiting maneuvers in patients with acute respiratory distress syndrome ventilated with protective ventilatory strategy.</p>	<p><i>Anesthesiology.</i> <u>2002 Apr</u></p>
<p>Background: A lung-protective ventilatory strategy with low tidal volume (VT) has been proposed for use in acute respiratory distress syndrome (ARDS). Alveolar derecruitment may occur during the use of a lung-protective ventilatory strategy and may be prevented by recruiting maneuvers. This study examined the hypothesis that the effectiveness of a recruiting maneuver to improve oxygenation in patients with ARDS would be influenced by the elastic properties of the lung and chest wall.</p> <p>Methods: Twenty-two patients with ARDS were studied during use of the ARDSNet lung-protective ventilatory strategy: VT was set at 6 ml/kg predicted body weight and positive end-expiratory pressure (PEEP) and inspiratory oxygen fraction (FiO₂) were set to obtain an arterial oxygen saturation of 90-95% and/or an arterial oxygen partial pressure (PaO₂) of 60- 80 mmHg (baseline). Measurements of PaO₂/FiO₂, static volume-pressure curve, recruited volume (vertical shift of the volume-pressure curve), and chest wall and lung elastance (Est_w and Est_L: esophageal pressure) were obtained on zero end-expiratory pressure, at baseline, and at 2 and 20 min after application of a recruiting maneuver (40 cm H₂O of continuous positive airway pressure for 40 s). Cardiac output (transesophageal Doppler) and mean arterial pressure were measured immediately before, during, and immediately after the recruiting maneuver. Patients were classified a priori as responders and nonresponders on the basis of the occurrence or nonoccurrence of a 50% increase in PaO₂/FiO₂ after the recruiting maneuver.</p> <p>Results: Recruiting maneuvers increased PaO₂/FiO₂ by 20 +/- 3% in nonresponders (n = 11) and by 175 +/- 23% (n = 11; mean +/- standard deviation) in responders. On zero end-expiratory pressure, Est_L (28.4 +/- 2.2 vs. 24.2 +/- 2.9 cm H₂O/l) and Est_w (10.4 +/- 1.8 vs. 5.6 +/- 0.8 cm H₂O/l) were higher in nonresponders than in responders (<i>P</i> < 0.01). Nonresponders had been ventilated for a longer period of time than responders (7 +/- 1 vs. 1 +/- 0.3 days; <i>P</i> < 0.001). Cardiac output and mean arterial pressure decreased by 31 +/- 2 and 19 +/- 3% in nonresponders and by 2 +/- 1 and 2 +/- 1% in responders (<i>P</i> < 0.01).</p> <p>Conclusions: Application of recruiting maneuvers improves oxygenation only in patients with early ARDS who do not have impairment of chest wall mechanics and with a large potential for recruitment, as indicated by low values of Est_L.</p>		