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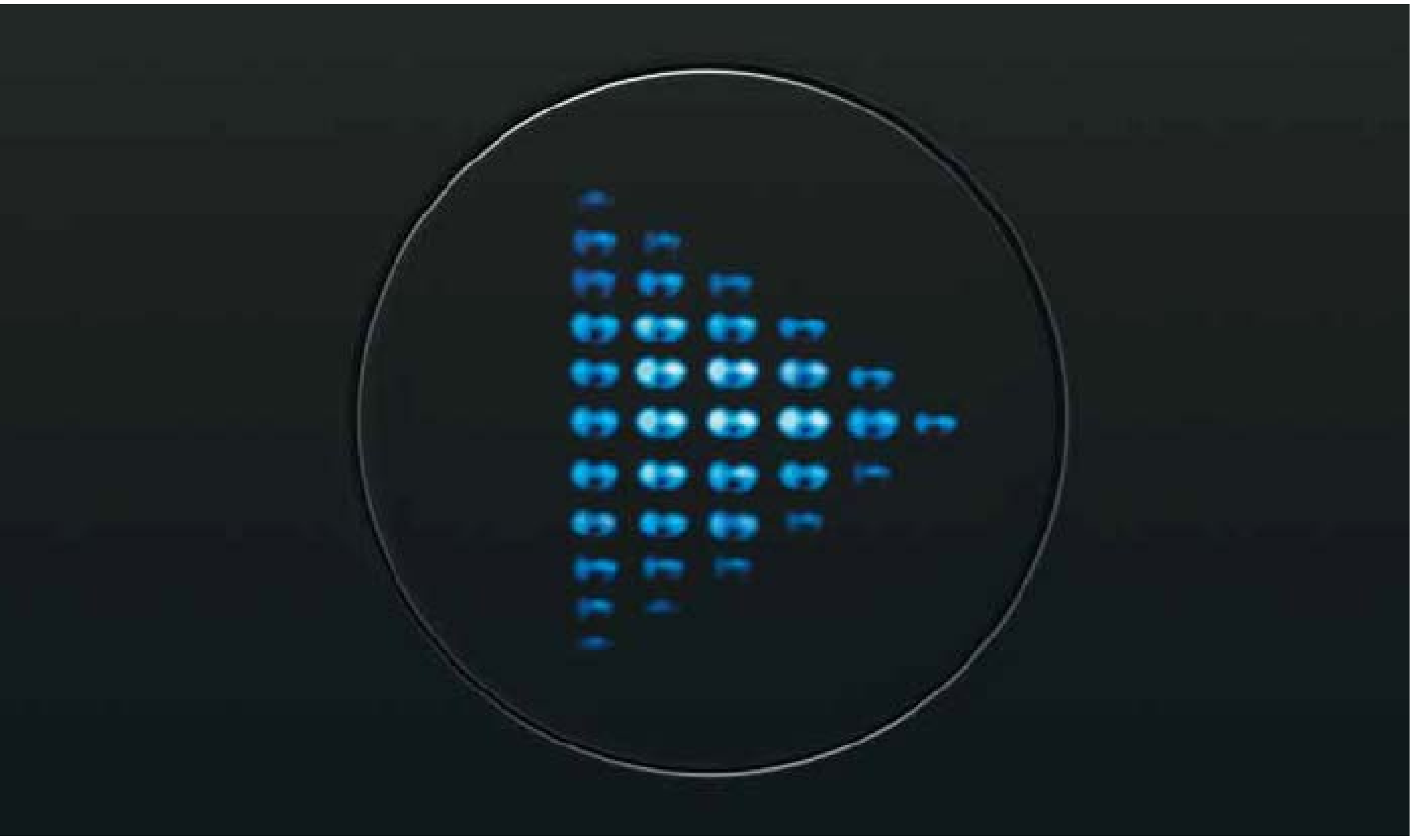

Literature List
Electrical Impedance Tomography

2015

Electrical Impedance Tomography (EIT)
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Categories

CLIN = *Clinical Study*

ES = *Experimental Study*

REV = *Review*

TEN = *Technical Note*

EDIT = *Editorial*

CR = *Case Report*

Electrical Impedance Tomography (EIT)
Literature List

REV	Gong B et al.	**Electrical impedance tomography: functional lung imaging on its way to clinical practice?**	*Expert Rev Respir Med. 2015 Dec; 9(6):721-37*

Abstract: Electrical impedance tomography (EIT) has the potential to become a bedside tool for monitoring and guiding ventilator therapy as well as tracking the development of chronic lung diseases. This review article summarizes recent publications (from 2011) dealing with the applications of pulmonary EIT. Original papers on EIT lung imaging in clinical settings are analyzed and divided into several categories according to the lung pathology of the study subjects. Studies on children and infants are presented separately from studies on adult patients. Information on the study objectives and main results, the number of studied patients, the performed ventilatory maneuvers or interventions and the analyzed EIT information is given. Limitations that hinder EIT to become a routinely used tool in a clinical setting are also discussed.

ES	Hammermüller S et al.	**Quantification of lung collapse during peep-titration by electrical impedance tomography in experimental ards - comparison with quantitative ct analysis**	*Intensive Care Medicine Experimental 2015 Dec, 3:A995*

Introduction: Tidal recruitment of nonaerated lung is a main cause of ventilator associated lung injury. CT as the gold standard for quantifying lung collapse (CT-collapse) is associated with certain risks for the patient (e.g. radiation exposure or transportation) and cannot be used for repeated assessments. Electrical impedance tomography (EIT) instead is a bed-side non-invasive radiation-free continuous technique for monitoring of changes in thoracic air content and distribution. EIT may also allow quantification of recruitable lunge collapse (EIT-collapse) [1].

Objectives: To study correlation and agreement between CT- and EIT-collapse during a decremental PEEP-titration after a lung recruitment maneuver (RM) for further validation of the technique for assessment of EIT-collapse.

Methods: We induced ARDS in anesthetized pigs by pulmonary acid (HCl) instillation until the PaO2/FiO2 remained stable < 200 mmHg. Tidal volume was 6 ml/kg body weight. We performed a RM (PEEP 40cmH2O; PIP 60cmH2O for 2 min) followed by decremental PEEP titration (starting from 26cmH2O in steps of 2 cmH2O). We recorded EIT-data and airway pressures simultaneously on each step and obtained end-expiratory CTs. CT-collapse in the entire lung was defined as the lung mass within -200 HU to +100 HU [2]. “Non-recruitable collapse” was defined as CT-collapse remaining after RM at PEEP = 26 cmH2O. Recruitable CT-collapse was calculated by multiplying the difference between CT-collapse at a certain PEEP-step and “non-recruitable collapse” by 100% and then dividing this product by the difference between total lung mass and “non-recruitable collapse”. EIT-collapse was calculated based on analysis of changes in EIT-pixel compliance [1]. The latter was estimated considering that local tidal volumes correlate well with local impedance variations. The concept used here assumes that the best compliance of a lung compartment reflects the number of functional lung units in that compartment, which, once opened, have equivalent compliances [1,3]. Thus, the relative amount of collapse (amount of lost units) within a given pixel can be inferred from the decrease in pixel compliance in relation to its “best compliance” [1,3]. Bland-Altman plots and within-subject linear regression were used for statistical analysis [2].

Results: We analyzed 60 data points from 11 pigs (weight 39 (range 37-42) kg). We found a strong within-subject correlation and clinically acceptable agreement between CT- and EIT-collapse (Figure 1) [4].

Conclusion: Our results support the potential of EIT for non-invasive bedside assessment of recruitable collapse.

ES	**Pfurtscheller K et al.**	**Effect of body position on ventilation distribution during PEEP titration in a porcine model of acute lung injury using advanced respiratory monitoring and electrical impedance tomography**	*Intensive Care Med Exp. 2015 Dec; 3: 3*

Background: Lung failure after acute lung injury remains a challenge in different clinical settings. Various interventions for restoration of gas exchange have been investigated. Recruitment of collapsed alveoli by positive end expiratory pressure (PEEP) titration and optimization of ventilation-perfusion ratio by prone positioning have been extensively described in animal and clinical trials. This animal study was conducted to investigate the effects of PEEP and positioning by means of advanced respiratory monitoring including gas exchange, respiratory mechanics, volumetric capnography and electrical impedance tomography.

Methods: After induction of acute lung injury by oleic acid and lung lavage, 12 domestic pigs were studied in randomly assigned supine or prone position during a PEEP titration trial with maximal PEEP of 30 mbar.

Results: Induction of lung injury resulted in significant deterioration of oxygenation [partial pressure of arterial oxygen/inspiratory fraction of oxygen (PaO_2/FiO_2): $p = 0.002$] and ventilation [partial pressure of arterial carbon dioxide ($PaCO_2$): $p = 0.002$] and elevated alveolar dead-space ratios (Valv/Vte: $p = 0.003$) in both groups. Differences in the prone and the supine group were significant for $PaCO_2$ at incremental PEEP 10 and 20 and at decremental PEEP 20 (20d) and 10 (10d), for PaO_2/FiO_2 at PEEP 10 and 10d and for alveolar dead space at PEEP 10d. Electrical impedance tomography revealed homogenous ventilation distribution in prone position during PEEP 20, 30 and 20d.

Conclusions: Prone position leads to improved oxygenation and ventilation parameters in a lung injury model. Respiratory monitoring with measurement of alveolar dead space and electrical impedance tomography may visualize optimized ventilation in a PEEP titration trial.

CR	**Goulart Rosa R et al.**	**Use of thoracic electrical impedance tomography as an auxiliary tool for alveolar recruitment maneuvers in acute respiratory distress syndrome: case report and brief literature review**	*Rev Bras Ter Intensiva. 2015 Dec; 27(4):406-411*

Abstract: Thoracic electrical impedance tomography is a real-time, noninvasive monitoring tool of the regional pulmonary ventilation distribution. Its bedside use in patients with acute respiratory distress syndrome has the potential to aid in alveolar recruitment maneuvers, which are often necessary in cases of refractory hypoxemia. In this case report, we describe the monitoring results and interpretation of thoracic electrical impedance tomography used during alveolar recruitment maneuvers in a patient with acute respiratory distress syndrome, with transient application of high alveolar pressures and optimal positive end-expiratory pressure titration. Furthermore, we provide a brief literature review regarding the use of alveolar recruitment maneuvers and monitoring using thoracic electrical impedance tomography in patients with acute respiratory distress syndrome.

CLIN	Cinnella G et al.	**Physiological Effects of the Open Lung Approach in Patients with Early, Mild, Diffuse Acute Respiratory Distress Syndrome**	*Anesthesiology. 2015 Nov; 123(5):1113-21*

Background: To test the hypothesis that in early, mild, acute respiratory distress syndrome (ARDS) patients with diffuse loss of aeration, the application of the open lung approach (OLA) would improve homogeneity in lung aeration and lung mechanics, without affecting hemodynamics.

Methods: Patients were ventilated according to the ARDS Network protocol at baseline (pre-OLA). OLA consisted in a recruitment maneuver followed by a decremental positive end-expiratory pressure trial. Respiratory mechanics, gas exchange, electrical impedance tomography (EIT), cardiac index, and stroke volume variation were measured at baseline and 20 min after OLA implementation (post-OLA). Esophageal pressure was used for lung and chest wall elastance partitioning. The tomographic lung image obtained at the fifth intercostal space by EIT was divided in two ventral and two dorsal regions of interest (ROI ventral and ROI dorsal).

Results: Fifteen consecutive patients were studied. The OLA increased arterial oxygen partial pressure/inspired oxygen fraction from 216 ± 13 to 311 ± 19 mmHg ($P < 0.001$) and decreased elastance of the respiratory system from 29.4 ± 3 cm H2O/l to 23.6 ± 1.7 cm H2O/l ($P < 0.01$). The driving pressure (airway opening plateau pressure − total positive end-expiratory pressure) decreased from 17.9 ± 1.5 cm H2O pre-OLA to 15.4 ± 2.1 post-OLA ($P < 0.05$). The tidal volume fraction reaching the dorsal ROIs increased, and consequently the $ROI_{Ventral/Dorsal}$ impedance tidal variation decreased from 2.01 ± 0.36 to 1.19 ± 0.1 ($P < 0.01$).

Conclusions: The OLA decreases the driving pressure and improves the oxygenation and lung mechanics in patients with early, mild, diffuse ARDS. EIT is useful to assess the impact of OLA on regional tidal volume distribution.

CLIN	Mauri T et al.	**Effects of Sigh on Regional Lung Strain and Ventilation Heterogeneity in Acute Respiratory Failure Patients Undergoing Assisted Mechanical Ventilation**	*Crit Care Med. 2015 Sep; 43(9):1823-31*

Objective: In acute respiratory failure patients undergoing pressure support ventilation, a short cyclic recruitment maneuver (Sigh) might induce reaeration of collapsed lung regions, possibly decreasing regional lung strain and improving the homogeneity of ventilation distribution. We aimed to describe the regional effects of different Sigh rates on reaeration, strain, and ventilation heterogeneity, as measured by thoracic electrical impedance tomography.

Design: Prospective, randomized, cross-over study.

Setting: General ICU of a single university-affiliated hospital.

Patients: We enrolled 20 critically ill patients intubated and mechanically ventilated with Pao2/Fio2 up to 300 mm Hg and positive end-expiratory pressure at least 5 cm H2O (15 with acute respiratory distress syndrome), undergoing pressure support ventilation as per clinical decision.

Interventions: Sigh was added to pressure support ventilation as a 35 cm H2O continuous positive airway pressure period lasting 3–4 seconds at different rates (no-Sigh vs 0.5, 1, and 2 Sigh(s)/min). All study phases were randomly performed and lasted 20 minutes.

Measurements and Main Results: In the last minutes of each phase, we measured arterial blood gases, changes in end-expiratory lung volume of nondependent and dependent regions, tidal volume reaching nondependent and dependent lung (Vt_{nondep} and Vt_{dep}), dynamic intratidal ventilation heterogeneity, defined as the average ratio of Vt reaching nondependent/Vt reaching dependent lung regions along inspiration (VtH_{it}). With Sigh, oxygenation improved ($p < 0.001$ vs no-Sigh), end-expiratory lung volume of nondependent and dependent regions increased ($p < 0.01$ vs no- Sigh), Vt_{nondep} showed a trend to reduction, and Vt_{dep} significantly decreased ($p = 0.11$ and $p < 0.01$ vs no-Sigh, respectively). VtH_{it} decreased only when Sigh was delivered at 0.5/min ($p < 0.05$ vs no-Sigh), while it did not vary during the other two phases.

Conclusions: Sigh decreases regional lung strain and intratidal ventilation heterogeneity. Our study generates the hypothesis that in ventilated acute respiratory failure patients, Sigh may enhance regional lung protection.

CLIN	Radke O C et al.	**Effect of Trigger Sensitivity on Redistribution of Ventilation During Pressure Support Ventilation Detected by Electrical Impedance Tomography**	*Anesth Pain Med. 2015 August; 5(4): e27439*

Background: In supine position, pressure support ventilation causes a redistribution of ventilation towards the ventral regions of the lung. Theoretically, a less sensitive support trigger would cause the patient to breathe more actively, potentially attenuating the effect of positive pressure ventilation.

Objectives: To quantify the effect of trigger setting, we assessed redistribution of ventilation during pressure support ventilation (PSV) using electrical impedance tomography (EIT).

Patients and Methods: With approval from the local ethics committee, six orthopedic patients were enrolled. All patients had general anesthesia with a laryngeal mask airway and a standardized anesthetic regimen (sufentanil, propofol and sevoflurane). Pressure support trigger settings varied between 2 and 15 L/minute and compared to unassisted spontaneous breathing. From EIT data, the center of ventilation (COV), the fraction of the total ventilation per region of interest (ROI) and intratidal gas distribution were calculated.

Results: At all trigger settings, pressure support ventilation caused a significant ventral shift of the center of ventilation compared with during spontaneous breathing, confirmed by the analysis by regions of interest. During spontaneous breathing, COV was not different from baseline values obtained before induction of anesthesia. During PSV, the intratidal regional gas distribution (ITV-analysis) revealed subtle changes during the early inspiratory phase not detected by the COV-analysis.

Conclusion: Pressure support ventilation, but not spontaneous breathing, induces a significant redistribution of ventilation towards the ventral region. The sensitivity of the support trigger appears to influence the distribution of ventilation only during the early phase of inspiration.

CLIN	Karsten J et al.	**Positive end-expiratory pressure titration at bedside using electrical impedance tomography in post-operative cardiac surgery patients**	*Acta Anaesthesiol Scand. 2015 Jul; 59(6):723-32*

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.

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.

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.

Conclusion: 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.

CLIN	Schaefer M S et al.	**Electrical impedance tomography during major open upper abdominal surgery: a pilot-study**	*BMC Anesthesiol. 2014 Jul 5; 14:51*

Background: Electrical impedance tomography (EIT) of the lungs facilitates visualization of ventilation distribution during mechanical ventilation. Its intraoperative use could provide the basis for individual optimization of ventilator settings, especially in patients at risk for ventilation-perfusion mismatch and impaired gas exchange, such as patients undergoing major open upper abdominal surgery. EIT throughout major open upper abdominal surgery could encounter difficulties in belt positioning and signal quality. Thus, we conducted a pilot-study and tested whether EIT is feasible in patients undergoing major open upper abdominal surgery.

Methods: Following institutional review board's approval and written informed consent, we included patients scheduled for major open upper abdominal surgery of at least 3 hours duration. EIT measurements were conducted prior to intubation, at the time of skin incision, then hourly during surgery until shortly prior to extubation and after extubation. Number of successful intraoperative EIT measurements and reasons for failures were documented. From the valid measurements, a functional EIT image of changes in tidal impedance was generated for every time point. Regions of interest were defined as horizontal halves of the picture. Monitoring of ventilation distribution was assessed using the center of ventilation index, and also using the total and dorsal ventilated lung area. All parameter values prior to and post intubation as well as extubation were compared. A $p < 0.05$ was considered statistically significant.

Results: A total of 120 intraoperative EIT measurements during major abdominal surgery lasting 4-13 hours were planned in 14 patients. The electrode belt was attached between the 2nd and 4th intercostal space. Consecutive valid measurements could be acquired in 13 patients (93%). 111 intraoperative measurements could be retrieved as planned (93%). Main obstacle was the contact of skin electrodes. Despite the high belt position, distribution of tidal volume showed a significant shift of ventilation towards ventral lung regions after intubation. This was reversed after weaning from mechanical ventilation.

Conclusions: Despite a high belt position, monitoring of ventilation distribution is feasible in patients undergoing major open upper abdominal surgery lasting from 4 to 13 hours. Therefore, further interventional trials in order to optimize ventilatory management should be initiated.

EDIT	Adler A et al.	**Why is EIT so hard, and what are we doing about it?**	*Physiol Meas. 2015 Jun; 36(6):1067-73*

Abstract: This focus issue of Physiological Measurement follows the successful 15th International Conference on Biomedical Applications of Electrical Impedance Tomography (EIT 2014) held at the Glen House Resort in Gananoque, Ontario, Canada, from 24–26 April 2014. The conference was organized by Andy Adler, of the department of systems and computer engineering at Carleton University, in Ottawa, Canada, and co-organized by Bartłomiej Grychtol, of the Fraunhofer Project Group for Automation in Medicine and Biotechnology in Mannheim, Germany. A new award for best student paper was presented to Winkler et al (2014) and runner-up award to Dodd and Mueller (2014). This continues the tradition of successful conferences on biomedical applications of electrical impedance tomography, as was the case with the 14th International Conference on Biomedical Applications of Electrical Impedance Tomography (EIT 2013), held on 22–25 April 2013 at Heilbad Heiligenstadt, Germany, and hosted by Uwe Pliquet of the Institut für Bioprozess- und Analysenmesstechnik. This year's conference is the 16th International Conference on Biomedical Applications of Electrical Impedance Tomography (EIT 2015) and is to be held in Neuchatel, Switzerland on 2–5 June 2015, and hosted by Josep Solà and Fabian Braun of the Centre Suisse d'électronique et de Microtechnique. This conference will be followed by a focus issue in Physiological Measurement that will be published in 2016. This issue contains papers stemming from discussion and feedback during the 2014 conference, and is also an opportunity for new researchers to join the community and describe recent innovations. There were 77 accepted submissions (including three keynotes, 45 oral presentation and 29 posters). All authors were invited to prepare new peer-reviewed papers for inclusion in this issue of Physiological Measurement. Manuscripts were put through a process of careful review before selection, and 18 were accepted (of 27 submitted), covering an important range of topics.

CLIN	Becher T et al.	**Influence of tidal volume on ventilation inhomogeneity assessed by electrical impedance tomography during controlled mechanical ventilation**	*Physiol Meas. 2015 Jun; 36(6):1137-46*

Abstract: The global inhomogeneity (GI) index is a parameter of ventilation inhomogeneity that can be calculated from images of tidal ventilation distribution obtained by electrical impedance tomography (EIT). It has been suggested that the GI index may be useful for individual adjustment of positive end-expiratory pressure (PEEP) and for guidance of ventilator therapy. The aim of the present work was to assess the influence of tidal volume (V_T) on the GI index values. EIT data from 9 patients with acute respiratory distress syndrome ventilated with a low and a high V_T of 5 ± 1 (mean ± SD) and 9 ± 1 ml kg−1 predicted body weight at a high and a low level of PEEP (PEEPhigh, PEEPlow) were analyzed. PEEPhigh and PEEPlow were set 2 cmH2O above and 5 cmH2O below the lower inflection point of a quasi-static pressure volume loop, respectively. The lower inflection point was identified at 8.1 ± 1.4 (mean ± SD) cmH2O, resulting in a PEEPhigh of 10.1 ± 1.4 and a PEEPlow of 3.1 ± 1.4 cmH2O. At PEEPhigh, we found no significant trend in GI index with low V_T when compared to high V_T (0.49 ± 0.15 versus 0.44 ± 0.09, $p = 0.13$). At PEEPlow, we found a significantly higher GI index with low V_T compared to high V_T (0.66 ± 0.19 versus 0.59 ± 0.17, $p = 0.01$). When comparing the PEEP levels, we found a significantly lower GI index at PEEPhigh both for high and low V_T. We conclude that high V_T may lead to a lower GI index, especially at low PEEP settings. This should be taken into account when using the GI index for individual adjustment of ventilator settings.

CLIN	Long Y et al.	**Positive End‑expiratory Pressure Titration after Alveolar Recruitment Directed by Electrical Impedance Tomography**	*Chin Med J (Engl). 2015 Jun 5; 128(11):1421-7*

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.

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 over‑distension and recruitment were monitored with EIT.

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.

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.

REV	Stankiewicz-Rudnicki M et al.	**Assessment of regional ventilation in acute respiratory distress syndrome by electrical impedance tomography**	*Anaesthesiol Intensive Ther. 2015 May ;47(1):77-81*

Abstract: Mechanical ventilation in acute respiratory distress syndrome (ARDS) incurs a risk of ventilator-associated lung injury (VALI) from inhomogeneous conditions and different properties of dependent and non-dependent lung regions at risk of atelectasis and overdistension, respectively. Electrical impedance tomography (EIT) offers regional ventilation assessment to optimise treatment with mechanical ventilation. This article provides an overview of scientific literature on the application of impedance tomography in acute respiratory distress syndrome. It also presents the results of EIT studies in different clinical situations that may be of use in implementing impedance tomography for treating ARDS.

REV	Kobylianskii J et al.	**Use Of Electrical Impedance Tomography During Mechanical Ventilation - A Systematic Review**	*Am J Respir Crit Care Med 191; 2015 May: A1642*

Introduction: Electrical Impedance Tomography (EIT) is a non-invasive, radiation-free imaging technique that can assess regional ventilation in order to guide appropriate lung-protective mechanical ventilation. Although the evidence base surrounding this technology has expanded rapidly, EIT has not yet become adopted into clinical practice. A likely barrier to the use of EIT in patient care is a lack of consensus regarding which EIT parameters should be monitored; to address this concern, it would be beneficial to summarize how EIT has been used. The primary aim of this review was to describe the current state of evidence surrounding the use of EIT in mechanical ventilation.

Methods: A comprehensive literature search (July 2014) was conducted within OVIDsp MEDLINE, OVIDsp EMBASE, EBSCOhost CINAHL, Cochrane CENTRAL, and Web of Science. We identified and included English language studies on the use of EIT during mechanical ventilation in large animals or adult humans.

Results: Our search yielded 559 unique publications. Manual search of conference proceedings and reference review yielded an additional 27 publications. After full text review, 176 studies were included. In the present review, we focus on the studies investigating the use of EIT in mechanically ventilated adult humans (n=78). The use of EIT in lung imaging was validated against other measures in 17 (22%) studies (Table 1). The majority of studies (38 studies; 49%) used EIT to measure the efficacy of ventilation-related interventions, including PEEP trials, airway suctioning, ventilation strategy, patient positioning, and recruitment maneuvers. 11 (14%) studies investigated the clinical application of EIT as a tool to optimize PEEP in protective ventilation. EIT was predominantly used to assess changes in lung volume, regional compliance, and ventilation distribution. A variety of indices were used to quantify ventilation distribution, including center of gravity, center of ventilation, homogeneity index, impedance ratio, regional ventilation delay, and global inhomogeneity index.

Conclusion: The evidence base surrounding the role of EIT imaging in mechanical ventilation is quickly expanding. Through diverse approaches, the field has moved towards understanding the reliability, validity, and interpretation of different EIT-based parameters. Future work should be conducted to synthesize the findings of existing literature to better understand the value and implications of EIT-based measures. This will help to inform the design of clinical trials evaluating EIT-based ventilation strategies, and facilitate its potential adoption into clinical practice.

REV	Ochiai R	**Mechanical ventilation of acute respiratory distress syndrome**	*J Intensive Care. 2015 May; 3(1): 25*

Abstract: Acute respiratory distress syndrome (ARDS) has been intensively and continuously studied in various settings, but its mortality is still as high as 30–40 %. For the last 20 years, lung protective strategy has become a standard care for ARDS, but we still do not know the best way to ventilate patients with ARDS. Tidal volume itself does not seem to have an important role to develop ventilator-induced lung injury (VILI), but the driving pressure, which is inspiratory plateau pressure—PEEP, is the most important to predict and affect the outcome of ARDS, though there is no safe limit for the driving pressure. There is so much controversy regarding what the best PEEP is, whether collapsed lung should be recruited, and what parameters should be measured and evaluated to improve the outcome of ARDS. Since the mechanical ventilation for patients with respiratory failure, including ARDS, is a standard care, we need more dynamic and regional information of ventilation and pulmonary circulation in the injured lungs to evaluate the efficacy of new type of treatment strategy. In addition to the CT scanning of the lung as the gold standard of evaluation, the electrical impedance tomography (EIT) of the lung has been clinically available to provide such information non-invasively and at the bedside. Various parameters have been tested to evaluate the homogeneity of regional ventilation, and EIT could provide us with the information of ventilator settings to minimize VILI.

TEN	Balleza-Ordaz M et al.	**Tidal volume monitoring by electrical impedance tomography (EIT)using different regions of interest (ROI): Calibration equations**	*Biomedical Signal Processing and Control Volume 18, 2015 Apr, Pages 102-109*

Abstract: A set of calibration equations was previously obtained to transform the lung impedance changes obtained by electrical impedance tomography (EIT), using all frame's elements, into a measurable volume signal. In order to study the goodness of the use of regions of interest (ROI) for lung ventilation monitoring, we considered 6 different ROI to obtain a calibration equation for each area. Our aim was to compare the results, determined by these areas, and those obtained by using all EIT image elements. Two ROI's were defined by those pixels with an impedance change higher than 30% and 70% of the maximum change value. These areas were called P30 and P70, respectively. Two other ROI were defined by bounding two areas by mouse, resembling P30 and P70 regions, which were called M30 and M70, respectively. The remainder was defined by two elliptical areas with an eccentricity of 0.8, and 25 and 32 pixels of mayor axis (E25p and E32p, respectively). Twenty healthy males and 24 chronic obstructive pulmonary disease (COPD) patients were considered. For small region (P30 and M30) we obtained a large dispersion in volume measurement, concluding that small regions are not suitable for monitoring the tidal changes in lung volume even for healthy subjects. The results obtained by the remainder areas, and by using EIT image were similar. Even a slight improvement in data dispersion was obtained by using some ROI. These optimal results, for healthy people, were those corresponding to P70 and M70 (volume dispersion improved from 12% with the whole EIT image to 9% using ROI), and for COPD patients improves volume dispersion from 32% using the whole EIT image to 27% by using E25p. Using not so small ROI, it is possible to estimate the total lung ventilation.

CR	Meira Dias O et al.	**Tracheobronchomalacia in a patient on invasive mechanical ventilation: the role of electrical impedance tomography in its detection and positive end-expiratory pressure titration**	*J Bras Pneumol. 2015 Mar-Apr; 41(2): 203–205*

Abstract: Tracheobronchomalacia (TBM) is a disorder caused by weakness of the tracheal and bronchial walls, together with softening of the supporting cartilage, resulting in excessive expiratory collapse. (1) Although some individuals with TBM are asymptomatic, others present with symptoms such as dyspnea, hemoptysis, wheezing, and chronic cough.(1-3) Because the symptoms are nonspecific, TBM can be easily overlooked or misdiagnosed as other obstructive airway diseases, including asthma and COPD.(4) In TBM patients with acute respiratory failure, noninvasive ventilation is a therapeutic option, because positive end-expiratory pressure (PEEP) can prevent airway collapse.(5-7) Kandaswamy et al. reported that, among patients with respiratory distress who failed weaning from mechanical ventilation or required reintubation in the ICU, the prevalence of TBM, identified on CT scans of the chest acquired only days before intubation, was 1.6%. However, to our knowledge, there have been no reports of TBM being diagnosed during invasive mechanical ventilation. Electrical impedance tomography (EIT) is a noninvasive, radiation-free monitoring tool that provides real-time imaging of ventilation at the bedside. Here, we report a case in which the combination of CT and EIT scans of the chest allowed us to make the diagnosis of TBM and to determine the best PEEP titration for preventing airway collapse in an intubated patient.

CLIN	Hsu C et al.	**Electrical impedance tomography monitoring in acute respiratory distress syndrome patients with mechanical ventilation during prolonged positive end-expiratory pressure adjustments**	*J Formos Med Assoc. 2015 Mar;115(3):195-202*

Background/purpose: The time required to reach oxygenation equilibrium after positive endexpiratory 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.

Methods: Nineteen mechanically ventilated ARDS patients were placed on baseline PEEP (PEEPB) for 1 hour, PEEPB_4 cmH2OPEEP (PEEPL) for 30 minutes, and PEEPBþ4cmH2OPEEP (PEEPH) 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 PEEPL, and 5 minutes, 15 minutes, 30 minutes, and 1 hour after PEEPH.

Results: PaO2/fraction of inspired oxygen (P/F ratio) decreased quickly from PEEPB to PEEPL, and stabilized 5 minutes after PEEPL. However the P/F ratio progressively increased from PEEPL to PEEPH, and a significantly higher P/F ratio and end-expiratory lung impedance were found at 60 minutes compared to 5 minutes after PEEPH. 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.

Conclusion: 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.

CLIN	**Bordes J et al.**	**Impact of Extraperitoneal Dioxyde Carbon Insufflation on Respiratory Function in Anesthetized Adults: A Preliminary Study Using Electrical Impedance Tomography and Wash-out/Wash-in Technic**	*Anesth Pain Med. 2015 March; 5(1): e22845*

Background: Extraperitoneal laparoscopy has become a common technique for many surgical procedures, especially for inguinal hernia surgery. Investigations of physiological changes occurring during extraperitoneal carbon dioxide (CO_2) insufflation mostly focused on blood gas changes. To date, the impact of extraperitoneal CO_2 insufflation on respiratory mechanics remains unknown, whereas changes in respiratory mechanics have been extensively studied in intraperitoneal insufflation.

Objectives: The aim of this study was to investigate the effects of extraperitoneal CO_2 insufflation on respiratory mechanics.

Patients and Methods: A prospective and observational study was performed on nine patients undergoing laparoscopic inguinal hernia repair. Anesthetic management and intraoperative care were standardized. All patients were mechanically ventilated with a tidal volume of 8 mL/kg using an Engström Carestation ventilator (GE Healthcare). Ventilation distribution was assessed by electrical impedance tomography (EIT). End-expiratory lung volume (EELV) was measured by a nitrogen wash-out/wash-in method. Ventilation distribution, EELV, ventilator pressures and hemodynamic parameters were assessed before extraperitoneal insufflation, and during insufflation with a PEEP of 0 cmH2O, 5 cmH20 and of 10 cmH20.

Results: EELV and thoracopulmonary compliance were significantly decreased after extraperitoneal insufflation. Ventilation distribution was significantly higher in ventral lung regions during general anesthesia and was not modified after insufflation. A 10 cmH20 PEEP application resulted in a significant increase in EELV, and a shift of ventilation toward the dorsal lung regions.

Conclusions: Extraperitoneal insufflation decreased EELV and thoracopulmonary compliance. Application of a 10 cmH20 PEEP increased EELV and homogenized ventilation distribution. This preliminary clinical study showed that extraperitoneal insufflation worsened respiratory mechanics, which may justify further investigations to evaluate the clinical impact.

CR	**Kotani T et al.**	**Electrical impedance tomography-guided prone positioning in a patient with acute cor pulmonale associated with severe acute respiratory distress syndrome**	*J Anesth. 2015 Oct; 30(1):161-5*

Abstract: Electrical impedance tomography (EIT) is a noninvasive technique used to assess regional gas distribution in the lung. We experienced a patient with acute cor pulmonale during high positive-pressure ventilation for the treatment of severe acute respiratory distress syndrome. Prone positioning was beneficial for unloading the right ventricle for treatment of acute cor pulmonale. EIT played a role in detecting lung derecruitment at the patient’s bedside. Impedance distribution in ventral, mid-ventral, middorsal, and dorsal layers before and 20 min after the start of prone positioning was 9, 48, 44, and 0 %, and 10, 25, 48, and 16 %, respectively. Lung recruitment monitored by EIT paralleled the improvement of PaO2/FIO2 from 123 to 239 mmHg. Timing of termination of prone positioning and ventilator settings such as lowering positive end-expiration pressure was determined to maintain dorsal recruitment as seen by EIT. The patient was weaned from mechanical ventilation on day 32 and discharged on day 200. EIT assessed the effects of prone positioning with real-time dynamic imaging and guided less injurious mechanical ventilation in a patient with acute cor pulmonale with dorsal lung derecruitment.

EDIT	**Van der Burg P S et al.**	**Electrical impedance tomography: effect of clinical interventions on (regional) lung volume in preterm infants**	*Faculty of Medicine (AMC-UvA) 2015 Feb; ISBN 9789491602313*

Abstract: Premature infants are at risk for low end-expiratory lung volume (EELV), which may compromise lung function and lead to respiratory failure. Respiratory interventions and nursing procedures are aimed to improve EELV in these infants. In this thesis, Pauline van der Burg has investigated the effects of these clinical interventions on lung volume, using electrical impedance tomography (EIT), a non-invasive lung volume measurement technique. This thesis it once again shows that EIT monitoring is feasible in preterm infants and, more importantly, adds support to its use because the volume changes measured in a cross-section of the thorax are representative for the whole lung in preterm infants. Moreover, it provides a clear example of how regional information obtained with EIT can assist the clinician in detecting asymmetry in lung ventilation as, for instance, is seen in case of unilateral atelectasis. Finally, it improves our understanding of preterm lung physiology and the effect of different less or non-invasive respiratory interventions, such as respiratory support, non-invasive surfactant administration, and body positioning. This information can be used to select the optimal intervention for common clinical problems in preterm infants.

REV	**Tharayil G M**	**Electrical Impedance Tomography - Watch the lungs breathe!**	*Indian Journal of Respiratory Care 4.1 2015 Jan: 547-553*

Abstract: Electrical Impedance Tomography (EIT) is a relatively new noninvasive tool in the management of patients on mechanical ventilators. It is a simple, user-friendly and radiation-free investigation to study the regional ventilation and distribution of ventilation particularly in patients with Acute Respiratory Distress Syndrome (ARDS). It empowers the clinician to take necessary steps for the management of collapsed, non-aerated regions of the lungs, to prevent regional overdistension of lungs which results in Ventilator Induced Lung Injury (VILI) and for early detection of pneumothorax. This is a short review focusing the basic principles, clinical applications and current evidence in the effectiveness of this modality in the routine respiratory care.

CLIN	**Caruana L et al.**	**The time taken for the regional distribution of ventilation to stabilise: an investigation using electrical impedance tomography**	*Anaesth Intensive Care. 2015 Jan; 43(1):88-91*

Abstract: Electrical impedance tomography is a novel technology capable of quantifying ventilation distribution in the lung in real time during various therapeutic manoeuvres. The technique requires changes to the patient's position to place the electrical impedance tomography electrodes circumferentially around the thorax. The impact of these position changes on the time taken to stabilise the regional distribution of ventilation determined by electrical impedance tomography is unknown. This study aimed to determine the time taken for the regional distribution of ventilation determined by electrical impedance tomography to stabilise after changing position. Eight healthy, male volunteers were connected to electrical impedance tomography and a pneumotachometer. After 30 minutes stabilisation supine, participants were moved into 60 degrees Fowler's position and then returned to supine. Thirty minutes was spent in each position. Concurrent readings of ventilation distribution and tidal volumes were taken every five minutes. A mixed regression model with a random intercept was used to compare the positions and changes over time. The anterior-posterior distribution stabilised after ten minutes in Fowler's position and ten minutes after returning to supine. Left-right stabilisation was achieved after 15 minutes in Fowler's position and supine. A minimum of 15 minutes of stabilisation should be allowed for spontaneously breathing individuals when assessing ventilation distribution. This time allows stabilisation to occur in the anterior-posterior direction as well as the left-right direction.