Literature List
Electrical Impedance Tomography

2020

Electrical Impedance Tomography (EIT)
Literature List 2020

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Categories

CLIN = Clinical Study

ES = Experimental Study

REV = Review

CR = Case Report

EDIT = Editorial

Electrical Impedance Tomography (EIT)
Literature List 2020

CR + REV	**Tomasino S, et al.**	**Electrical Impedance Tomography and Prone Position During Ventilation in COVID-19 Pneumonia: Case Reports and a Brief Literature Review**	*Semin Cardiothorac Vasc Anesth* ***2020 Dec***

Abstract: At the end of 2019, a novel coronavirus (COVID-19) was identified as the cause of a cluster of pneumonia cases, with high needs of mechanical ventilation in critically ill patients. It is still unclear whether different types of COVID-19 pneumonia require different ventilator strategies. With electrical impedance tomography (EIT) we evaluated, in real time and bedside, the distribution of ventilation in the different pulmonary regions before, during, and after pronation in COVID-19 respiratory failure. We present a brief literature review of EIT in non-COVID-19 patients and a report of 2 COVID-19 patients: one that did not respond well and another one that improved during and after pronation. EIT might be a useful tool to decide whether prone positioning should or should not be used in COVID-19 pneumonia.

CLIN	**Perier F, et al.**	**Electrical impedance tomography to titrate positive end-expiratory pressure in COVID-19 acute respiratory distress syndrome**	*Crit Care* ***2020 Dec***

Rationale: Patients with coronavirus disease-19-related acute respiratory distress syndrome (C-ARDS) could have a specific physiological phenotype as compared with those affected by ARDS from other causes (NC-ARDS).

Objectives: To describe the effect of positive end-expiratory pressure (PEEP) on respiratory mechanics in C-ARDS patients in supine and prone position, and as compared to NC-ARDS. The primary endpoint was the best PEEP defined as the smallest sum of hyperdistension and collapse.

Methods: Seventeen patients with moderate-to-severe C-ARDS were monitored by electrical impedance tomography (EIT) and evaluated during PEEP titration in supine (n = 17) and prone (n = 14) position and compared with 13 NC-ARDS patients investigated by EIT in our department before the COVID-19 pandemic.

Results: As compared with NC-ARDS, C-ARDS exhibited a higher median best PEEP (defined using EIT as the smallest sum of hyperdistension and collapse, 12 [9, 12] vs. 9 [6, 9] cmH2O, $p < 0.01$), more collapse at low PEEP, and less hyperdistension at high PEEP. The median value of the best PEEP was similar in C-ARDS in supine and prone position: 12 [9, 12] vs. 12 [10, 15] cmH2O, $p = 0.59$. The response to PEEP was also similar in C-ARDS patients with higher vs. lower respiratory system compliance.

Conclusion: An intermediate PEEP level seems appropriate in half of our C-ARDS patients. There is no solid evidence that compliance at low PEEP could predict the response to PEEP.

CLIN	**Becher TH, et al.**	**Individualization of PEEP and Tidal Volume in ARDS Patients with Electrical Impedance Tomography**	*Preprint.* ***2020 Dec***

Background: In mechanically ventilated patients with acute respiratory distress syndrome (ARDS), electrical impedance tomography (EIT) provides information on alveolar cycling and overdistension as well as assessment of recruitability at the bedside. We developed a protocol for individualization of positive end-expiratory pressure (PEEP) and tidal volume (VT) utilizing EIT-derived information on recruitability, overdistension and alveolar cycling. The aim of this study was to assess whether the EIT-based protocol allows individualization of ventilator settings without causing lung overdistension, and to evaluate its effects on respiratory system compliance, oxygenation and alveolar cycling. .

Methods: 20 patients with ARDS were included. Initially, patients were ventilated according to the recommendations of the ARDS-Network with a VT of 6 ml per kg predicted body weight and PEEP adjusted according to the fraction of inspired oxygen. Subsequently, ventilator settings were adjusted according to the EIT-based protocol once every 30 minutes for a duration of 4 hours. To assess global overdistension, we determined whether lung stress and strain remained below 27 and 2.0, respectively.

Results: We found that prospective optimization of mechanical ventilation with EIT led to global lung stress below 27 mbar in all patients and global strain below 2.0 in 19 out of 20 patients. Compliance remained similar while oxygenation was significantly improved and alveolar cycling was reduced after EIT-based optimization.

Conclusion: Adjustment of PEEP and VT using the EIT-based protocol led to individualization of ventilator settings with improved oxygenation and reduced alveolar cycling without promoting global overdistension.

CR	**Shono A, Kotani T, Frerichs I**	**Personalisation of Therapies in COVID-19 Associated Acute Respiratory Distress Syndrome, Using Electrical Impedance Tomography**	*Journal of Critical Care Medicine* ***2020 Nov***

Introduction: Each patient suffering from severe coronavirus COVID-19-associated acute respiratory distress syndrome (ARDS), requiring mechanical ventilation, shows different lung mechanics and disease evolution. Therefore, lung protective strategies should be personalised for the individual patient.

Case Presentation: A 64-year-old male patient was intubated ten days after the symptoms of COVID-19 infection presented. He was placed in the prone position for sixteen hours, resulting in a marked improvement in oxygenation. However, after being returned to the supine position, his SpO2 rapidly dropped from 98% to 91%, and electrical impedance tomography showed less ventilation at the dorsal region and a ventral shift of ventilation distribution. An incremental and decremental PEEP trial under electrical impedance tomography monitoring was carried out, confirming that the dependent lung regions were recruited with increased pressures and homogenous ventilation distribution could be provided with 14 cmH2O of PEEP. The optimal settings were reassessed next day after returning from the second session of the prone position. After four prone position-sessions in five days, oxygenation was stabilised and eventually the patient was discharged.

Conclusions: Patients with COVID-19 associated ARDS require individualised ventilation support depending on the stage of their disease. Daily PEEP trial monitored by electrical impedance tomography can provide important information to tailor the respiratory therapies.

CLIN	**Basile MC, et al.**	**Nasal high flow higher than 60 L/min in patients with acute hypoxemic respiratory failure: a physiological study**	*Crit Care* ***2020 Nov***

Background: Nasal high flow delivered at flow rates higher than 60 L/min in patients with acute hypoxemic respiratory failure might be associated with improved physiological effects. However, poor comfort might limit feasibility of its clinical use.

Methods: We performed a prospective randomized cross-over physiological study on 12 ICU patients with acute hypoxemic respiratory failure. Patients underwent three steps at the following gas flow: 0.5 L/kg PBW/min, 1 L/kg PBW/min, and 1.5 L/kg PBW/min in random order for 20 min. Temperature and FiO_2 remained unchanged. Toward the end of each phase, we collected arterial blood gases, lung volumes, and regional distribution of ventilation assessed by electrical impedance tomography (EIT), and comfort.

Results: In five patients, the etiology was pulmonary; infective disease characterized seven patients; median PaO_2/FiO_2 at enrollment was 213 [IQR 136–232]. The range of flow rate during NHF 1.5 was 75–120 L/min. PaO2/ FiO2 increased with flow, albeit non significantly ($p = 0.064$), PaCO2 and arterial pH remained stable ($p = 0.108$ and $p = 0.105$). Respiratory rate decreased at higher flow rates ($p = 0.014$). Inhomogeneity of ventilation decreased significantly at higher flows ($p = 0.004$) and lung volume at end-expiration significantly increased ($p = 0.007$), but mostly in the non-dependent regions. Comfort was significantly poorer during the step performed at the highest flow ($p < 0.001$).

Conclusions: NHF delivered at rates higher than 60 L/min in critically ill patients with acute hypoxemic respiratory failure is associated with reduced respiratory rate, increased lung homogeneity, and additional positive pressure effect, but also with worse comfort.

CLIN	**Spatenkova V, et al.**	**Evaluation of regional ventilation by electric impedance tomography during percutaneous dilatational tracheostomy in neurocritical care: a pilot study**	*BMC Neurology* ***2020 Oct***

Background: Percutaneous dilatational tracheostomy (PDT) has become a widely performed technique in neurocritical care, which is however known to be accompanied by some risks to the patient. The aim of this pilot study was to assess the derecruitment effects of PDT with the electric impedance tomography (EIT) during the PDT procedure in neurocritical care.

Methods: The prospective observational pilot study investigated 11 adult, intubated, mechanically ventilated patients with acute brain disease. We recorded EIT data to determine regional ventilation delay standard deviation (RVD SD), compliance win (CW) and loss (CL), end-expiratory lung impedance (EELI), with the EIT belt placed at the level of Th 4 before, during and after the PDT, performed in the standard PDT position ensuring hyperextension of the neck.

Results: From 11 patients, we finally analyzed EIT data in 6 patients - EIT data of 5 patients have been excluded due to the insufficient EIT recordings. The mean RVD SD post-PDT decreased to 7.00 ± 1.29% from 7.33 ± 1.89%. The mean post-PDT CW was 27.33 ± 15.81 and PDT CL 6.33 ± 6.55. Only in one patient, where the trachea was open for 170 s, was a massive dorsal collapse (ΔEELI − 25%) detected. In other patients, the trachea was open from 15 to 50 s.

Conclusion: This pilot study demonstrated the feasibility of EIT to detect early lung derecruitment occurring due to the PDT procedure. The ability to detect regional changes in ventilation could be helpful in predicting further progression of ventilation impairment and subsequent hypoxemia, to consider optimal ventilation regimes or time schedule and type of recruitment maneuvres required after the PDT.

ES	**Hahn G, et al.**	**Monitoring lung impedance changes during long-term ventilator-induced lung injury ventilation using electrical impedance tomography**	*Physiol. Meas.* ***2020 Oct***

Objective: The target of this methodological evaluation was the feasibility of long-term monitoring of changes in lung conditions by time-difference electrical impedance tomography (tdEIT). In contrast to ventilation monitoring by tdEIT, the monitoring of end-expiratory (EELIC) or end-inspiratory (EILIC) lung impedance change always requires a reference measurement.

Approach: To determine the stability of the used Pulmovista 500® EIT system, as a prerequisite it was initially secured on a resistive phantom for 50 h. By comparing the slopes of EELIC for the whole lung area up to 48 h from 36 pigs ventilated at six positive end-expiratory pressure (PEEP) levels from 0 to 18 cmH2O we found a good agreement (range of r2 = 0.93–1.0) between absolute EIT (aEIT) and tdEIT values. This justified the usage of tdEIT with its superior local resolution compared to aEIT for long-term determination of EELIC.

Main results: The EELIC was between −0.07 Ωm day−1 at PEEP 4 and −1.04 Ωm day−1 at PEEP 18 cmH2O. The complex local time pattern for EELIC was roughly quantified by the new parameter, centre of end-expiratory change (CoEEC), in equivalence to the established centre of ventilation (CoV). The ventrally located mean of the CoV was fairly constant in the range of 42%–46% of thorax diameter; however, on the contrary, the CoEEC shifted from about 40% to about 75% in the dorsal direction for PEEP levels of 14 and 18 cmH2O.

Significance: The observed shifts started earlier for higher PEEP levels. Changes of EELI could be precisely monitored over a period of 48 h by tdEIT on pigs.

CLIN	**Hickmann CE, et al.**	**Acute Effects of Sitting Out of Bed and Exercise on Lung Aeration and Oxygenation in Critically Ill Subjects**	*Respir. Care* ***2020 Sep***

Background: Early mobilization during critical illness is safe and has beneficial effects on functional outcomes. However, its impact on pulmonary function has not been thoroughly explored. We hypothesized that a sitting position out of bed coupled with exercise could result in an improvement in oxygenation and lung aeration. .

Methods: The study was conducted on a cohort of adult subjects within a week of their admission to an ICU. Subjects were transferred to a chair and undertook a 15-min session of exercise, either active or passive. Subjects in the control group were only transferred to a chair. Electrical impedance tomography, a reliable bedside technique monitoring regional lung aeration and the distribution of ventilation, was continuously performed, and blood gases were assessed at baseline and 20 min post-exercise.

Results: The cohort included 40 subjects, 17 of whom were mechanically ventilated and 23 spontaneously breathing. The control group for each modality consisted of 5 mechanically ventilated or 5 spontaneously breathing subjects. Mild hypoxemia was present in 45% of the spontaneously breathing cohort, whereas the mechanically ventilated subjects demonstrated moderate (50%) or severe (12%) hypoxemia. Compared with the control group, early mobilization induced a significant increase in lung aeration. In mechanically ventilated subjects, lung aeration increased, especially in the anterior lung regions (mean impedance [95% CI]: T1 (baseline in bed) = 1,265 [691-1,839]; T2 (chair sitting) = 2,003 [1,042-2,963]; T3 (exercise) = 1,619 [810 2,427]; T4 (post exercise in chair) = 2,320 [1,186-3,455]). In spontaneously breathing subjects, lung aeration increased mainly in the posterior lung regions (mean impedance [95% CI]: T1 = 380 [124-637]; T2 = 655 [226-1,084]; T3 = 621 [335-906]; T4 = 600 [340-860]). [Formula: see text] increased, especially in subjects with lower [Formula: see text] at baseline (< 200) (133 ± 31 to 158 ± 48, P = .041).

Conclusions: For critically ill subjects, a sitting position and exercise increased lung aeration and were associated with an improvement in [Formula: see text] in the more severely hypoxemic subjects.

CLIN	**He H, et al.**	**Influence of overdistension/recruitment induced by high positive end-expiratory pressure on ventilation–perfusion matching assessed by electrical impedance tomography with saline bolus.**	*Critical Care* ***2020 Sep***

Background: High positive end-expiratory pressures (PEEP) may induce overdistension/recruitment and affect ventilation–perfusion matching (VQMatch) in mechanically ventilated patients. This study aimed to investigate the association between PEEP-induced lung overdistension/recruitment and VQMatch by electrical impedance tom

Methods: The study was conducted prospectively on 30 adult mechanically ventilated patients: 18/30 with ARDS and 12/30 with high risk for ARDS. EIT measurements were performed at zero end-expiratory pressures (ZEEP) and subsequently at high (12–15 cmH_2O) PEEP. The number of overdistended pixels over the number of recruited pixels (O/R ratio) was calculated, and the patients were divided into low O/R (O/R ratio < 15%) and high O/R groups (O/R ratio ≥ 15%). The global inhomogeneity (GI) index was calculated to evaluate the ventilation distribution. Lung perfusion image was calculated from the EIT impedance–time curves caused by 10 ml 10% NaCl injection during a respiratory pause (> 8 s). DeadSpace%, Shunt%, and VQMatch% were calculated based on lung EIT perfusion and ventilation images. ography (EIT).

Results: Increasing PEEP resulted in recruitment mainly in dorsal regions and overdistension mainly in ventral regions. ΔVQMatch% (VQMatch% at high PEEP minus that at ZEEP) was significantly correlated with recruited pixels ($r = 0.468$, $P = 0.009$), overdistended pixels ($r = -0.666$, $P < 0.001$), O/R ratio ($r = -0.686$, $P < 0.001$), and ΔSpO_2 ($r = 0.440$, $P = 0.015$). Patients in the low O/R ratio group (14/30) had significantly higher Shunt% and lower VQMatch% than those in the high O/R ratio group (16/30) at ZEEP but not at high PEEP. Comparable DeadSpace% was found in both groups. A high PEEP caused a significant improvement of VQMatch%, DeadSpace%, Shunt%, and GI in the low O/R ratio group, but not in the high O/R ratio group. Using O/R ratio of 15% resulted in a sensitivity of 81% and a specificity of 100% for an increase of VQMatch% > 20% in response to high PEEP.

Conclusions: Change of ventilation–perfusion matching was associated with regional overdistention and recruitment induced by PEEP. A low O/R ratio induced by high PEEP might indicate a more homogeneous ventilation and improvement of VQMatch.

CLIN	**Fu Y, et al.**	**Monitoring bronchoalveolar lavage with electrical impedance tomography: first experience in a patient with COVID-19**	*Physiol. Meas.* ***2020 Sep***

Objectives: Patients with the novel coronavirus disease (COVID-19) often have airway secretions that severely compromise ventilation. This study investigates electrical impedance tomography (EIT) monitoring of a therapeutic bronchoalveolar lavage (BAL) in a patient with COVID-19.

Approach: A patient with COVID-19 developed acute respiratory distress syndrome requiring mechanical ventilation. He received regional BAL to remove mucus in the small airways (20 ml × 5). Regional ventilation changes before BAL, 30 min after and in the following days, were monitored with EIT.

Main Results: Regional ventilation worsened shortly after BAL and improved in the following days. The improvement of the oxygenation did not exactly match the ventilation improvement, which indicated a possible ventilation/perfusion mismatch.

Significance: Therapeutic BAL might improve regional ventilation for COVID-19 and EIT could be a useful tool at the bedside to monitor the ventilation treatment of COVID-19.

CLIN	**Yuan S, et al.**	**Effect of Early Mobilization from Bed to Wheel Chair on Regional Ventilation Distribution Assessed by Electrical Impedance Tomography in Respiratory Failure Patients**	*Preprint* ***2020 Aug***

Backgrounds: There was limited knowledge about the effect of early mobilization on regional lung ventilation in patients with respiratory failure. The aim of the study was to examine whether electrical impedance tomography (EIT) could help to predict the improvement in ventilation distribution due to mobilization.

Methods: Forty-one patients with respiratory failure, who had weaned from ventilator and received early mobilization were prospectively enrolled in this study. EIT was used to assess regional lung ventilation distributions at 4 timepoints during the early mobilization from bed to wheelchair (Tbase: baseline, supine position at the bed, T30min: sitting position on the wheelchair after 30min, T60min: sitting position on the wheelchair after 60min, Treturn: return to supine position on the bed after early mobilization). The EIT-based global inhomogeneity (GI) and center of ventilation (CoV) indices were calculated. EIT images were equally divided into four ventral-to-dorsal horizontal regions of interest (ROIs 1-4). Depending on the improvement of ventilation distribution in dependent regions at T60min (threshold set to 15%), patients were divided into recruited (DR) and non-recruited (Non-DR) groups.

Results: From the bed to the wheelchair, a significant and continuous increase of dependent regional ventilation distribution (ROI 3+4: baseline vs. T30min, vs. T60min: 45.9±12.1 vs. 48.7±11.6 vs. 49.9±12.6, p=0.015) and COV (COV baseline vs. T30min, vs. T60min: 48.2±10.1 vs. 50.1±9.2 vs. 50.5±9.6, p=0.003). Besides, there was a significant decrease of GI at T60min. Patients in the DR group (n=18) had significantly higher oxygenation than the Non-DR group (n=23) after early mobilization. ROI4Tbase was significantly negatively correlated to ΔSpO2 (R=0.72, p＜0.001). Using a cut-off value of 6.5%, ROI4Tbase had a 79.2% specificity and 58.8% sensitivity to predict response of dependent region recruitment due to early mobilization. The corresponding area under curve was 0.806 (95%CI, 0.677-0.936).

Conclusions: EIT may be a promising tool to predict the ventilation improvement resulted from early mobilization.

CR	**Tatham KC, et al.**	**Helmet interface increases lung volumes at equivalent ventilator pressures compared to the face mask interface during non-invasive ventilation**	*Crit Care* ***2020 Aug***

Introduction: During routine care of two patients with acute hypoxemic respiratory failure, we used electrical impedance tomography ('EIT', Draeger Pulmovista 500) to monitor ventilation while transitioning from face mask to helmet NIV. The transition to helmet NIV was a clinical decision prompted by worsening respiratory failure on face mask NIV, with the goal of avoiding intubation…

ES	**Sun XM, et al.**	**Derecruitment volume assessment derived from pressure-impedance curves with electrical impedance tomography in experimental acute lung injury**	*Journal of International Medical Research* ***2020 Aug***

Objective: To investigate the accuracy of derecruitment volume (VDER) assessed by pressure–impedance (P-I) curves derived from electrical impedance tomography (EIT).

Methods: Six pigs with acute lung injury received decremental positive end-expiratory pressure (PEEP) from 15 to 0 in steps of 5 cmH2O. At the end of each PEEP level, the pressure–volume (P-V) curves were plotted using the low constant flow method and release maneuvers to calculate the VDER between the PEEP of setting levels and 0 cmH2O (VDER-PV). The VDER derived from P-I curves that were recorded simultaneously using EIT was the difference in impedance at the same pressure multiplied by the ratio of tidal volume and corresponding tidal impedance (VDER-PI). The regional P-I curves obtained by EIT were used to estimate VDER in the dependent and nondependent lung.

Results: The global lung VDER-PV and VDER-PI showed close correlations ($r = 0.948$, $P<0.001$); the mean difference was 48 mL with limits of agreement of −133 to 229 mL. Lung derecruitment extended into the whole process of decremental PEEP levels but was unevenly distributed in different lung regions.

Conclusions: P-I curves derived from EIT can assess VDER and provide a promising method to estimate regional lung derecruitment at the bedside.

CLIN	**Sang L, et al.**	**Qualitative and quantitative assessment of pendelluft: a simple method based on electrical impedance tomography**	*Ann Transl Med* ***2020 Aug***

Background: Pendelluft, defined as asynchronous alveolar ventilation, is caused by different regional time constants or dynamic pleural pressure variations. The aim of the present study was to propose a simple method to evaluate pendelluft based on electrical impedance tomography (EIT). The efficacy of this method was demonstrated in well-known pendelluft scenarios in 6 patients.

Methods: Two patients with flail chest after accidents, two patients with acute respiratory distress syndrome (ARDS) and two patients with acutely exacerbated obstructive lung disease were prospectively included. EIT measurements were performed before and after surgery (in patients with flail chest, who had video-assisted thoracoscopic surgery with ribs fixation), or at two different levels of positive end-expiratory pressure (PEEP; ARDS patients), or two different time points (obstructive lung disease). Pendelluft was assessed by regional phase shift (defined as time difference between global and regional impedance-time curves) and amplitude differences (defined as the impedance difference between sum of all regional tidal variation and the global tidal variation).

Results: In patients with flail chest, pendelluft diminished several days after surgery (pendelluft amplitude normalized to tidal impedance variation reduced from 88% to 2% in one patient, 12% to 2% in the other). Increased PEEP reduced the amplitude of pendelluft (from 3% to 0% in one patient, 20% to 2% in the other) but not necessarily the phase shifts (average time differences were <0.1 second for both patients for both ins- and expiration) in ARDS patients. Pendelluft assessment in obstructive lung diseases reflected the change in airway resistance (from 5% to 1% in one patient after broncholytic medication administration, as airway resistance fell from 15 to 11 cmH2O/L/s; from 9% to 35% in the other patient with acute exacerbation, the corresponding airway resistance increased from 15 to 22 cmH2O/L/s).

Conclusions: The proposed EIT-based method can be used to evaluate the degree of pendelluft in dimension of phase shift and amplitude difference.

CLIN	**Riva T, et al.**	**Measurement of airway pressure during high-flownasal therapy in apnoeic oxygenation: a randomised controlled crossover trial**	*Anaesthesia* ***2020 Aug***

Summary: It is recognised that high-flow nasal therapy can prevent desaturation during airway management. Studies in spontaneously breathing patients show an almost linear relationship between flow rate and positive airway pressure in the nasopharynx. Positive airway pressure has been suggested as one of the possible mechanisms explaining how high-flow nasal therapy works. However, data on pressures generated by high-flow nasal therapy in apnoeic adults under general anaesthesia are absent. This randomised controlled crossover trial investigated airway pressures generated by different flow rates during high-flow nasal therapy in anaesthetised and paralysed apnoeic patients, comparing pressures with closed and open mouths. Following induction of anaesthesia and neuromuscular blockade, a continuous jaw thrust was used to enable airway patency. Airway pressure was measured in the right main bronchus, the middle of the trachea and the pharynx, using a fibreoptically-placed catheter connected to a pressure transducer. Each measurement was randomised with respect to closed or open mouth and different flow rates. Twenty patients undergoing elective surgery were included (mean (SD) age 38 (18) years, BMI 25.0 (3.3) kg.m-2, nine women, ASA physical status 1 (35%), 2 (55%), 3 (10%). While closed mouths and increasing flow rates demonstrated non-linear increases in pressure, the pressure increase was negligible with an open mouth. Airway pressures remained below 10 cmH2O even with closed mouths and flow rates up to 80 l.min−1; they were not influenced by catheter position. This study shows an increase in airway pressures with closed mouths that depends on flow rate. The generated pressure is negligible with an open mouth. These data question positive airway pressure as an important mechanism for maintenance of oxygenation during apnoea.

CLIN	**Longhini F, et al.**	**Chest physiotherapy improves lung aeration in hypersecretive critically ill patients: a pilot randomized physiological study**	*Critical Care* ***2020 Aug***

Background: Besides airway suctioning, patients undergoing invasive mechanical ventilation (iMV) benefit of different combinations of chest physiotherapy techniques, to improve mucus removal. To date, little is known about the clearance effects of oscillating devices on patients with acute respiratory failure undergoing iMV. This study aimed to assess (1) the effects of high-frequency chest wall oscillation (HFCWO) on lung aeration and ventilation distribution, as assessed by electrical impedance tomography (EIT), and (2) the effect of the association of HFCWO with recruitment manoeuvres (RM).

Methods: Sixty critically ill patients, 30 classified as normosecretive and 30 as hypersecretive, who received ≥ 48 h of iMV, underwent HFCWO; patients from both subgroups were randomized to receive RM or not, according to two separated randomization sequences. We therefore obtained four arms of 15 patients each. After baseline record (T0), HFCWO was applied for 10 min. At the end of the treatment (T1) or after 1 (T2) and 3 h (T3), EIT data were recorded. At the beginning of each step, closed tracheobronchial suctioning was performed. In the RM subgroup, tracheobronchial suctioning was followed by application of 30 cmH2O to the patient's airway for 30 s. At each step, we assessed the change in end-expiratory lung impedance (ΔEELI) and in tidal impedance variation (ΔTIV), and the center of gravity (COG) through EIT. We also analysed arterial blood gases (ABGs).

Results: ΔTIV and COG did not differ between normosecretive and hypersecretive patients. Compared to T0, ΔEELI significantly increased in hypersecretive patients at T2 and T3, irrespective of the RM; on the contrary, no differences were observed in normosecretive patients. No differences of ABGs were recorded.

Conclusions: In hypersecretive patients, HFCWO significantly improved aeration of the dorsal lung region, without affecting ABGs. The application of RM did not provide any further improvements.

CLIN	**Forsberg I-M, et al.**	**Lung volume changes in Apnoeic Oxygenation using Transnasal Humidified Rapid-Insufflation Ventilatory Exchange (THRIVE) compared to mechanical ventilation in adults undergoing laryngeal surgery**	*Acta Anaesthesiol Scand* ***2020 Aug***

Background: Transnasal Humidified Rapid-Insufflation Ventilatory Exchange (THRIVE) using high-flow 100% oxygen during apnoea has gained increased use during difficult airway management and laryngeal surgery due to a slower carbon dioxide rise compared to traditional apnoeic oxygenation. We have previously demonstrated high arterial oxygen partial pressures and an increasing arterial-alveolar carbon dioxide difference during THRIVE. Primary aim of this study was to characterise lung volume changes measured with electrical impedance tomography during THRIVE compared to mechanical ventilation.

Methods: Thirty adult patients undergoing laryngeal surgery under general anaesthesia were randomised to THRIVE or mechanical ventilation. Subjects were monitored with electrical impedance tomography and repeated blood gas measurement perioperatively. The THRIVE group received 100% oxygen at 70 l min-1 during apnoea. The mechanical ventilation group was intubated and normoventilated with an FiO2 of 0.4.

Results: Mean age were 48.2 (19.9) and 51.3 (12.3) years, and BMI 26.0 (4.5) and 26.0 (3.9) in the THRIVE and mechanical ventilation group respectively. Mean apnoea time in the THRIVE group was 17.9 (4.8) min. Mean apnoea to end-of-surgery time was 28.1 (12.8) min in the mechanical ventilation group. No difference in delta End Expiratory Lung Impedance was seen between groups over time. In the THRIVE group all but three subjects were well oxygenated during apnoea. THRIVE was discontinued for the three patients who desaturated.

Conclusions: No difference in lung volume change over time, measured by electrical impedance tomography, was detected when using THRIVE compared to mechanical ventilation during laryngeal surgery.

CLIN	**Girrbach F, et al.**	**Individualised positive end-expiratory pressure guided by electrical impedance tomography for robot-assisted laparoscopic radical prostatectomy: a prospective, randomised controlled clinical trial**	*British Journal of Anaesthesia* ***2020 Jul***

Background: Robot-assisted laparoscopic radical prostatectomy requires general anaesthesia, extreme Trendelenburg positioning and capnoperitoneum. Together these promote impaired pulmonary gas exchange caused by atelectasis and may contribute to postoperative pulmonary complications. In morbidly obese patients, a recruitment manoeuvre (RM) followed by individualised PEEP improves intraoperative oxygenation and end-expiratory lung volume (EELV). We hypothesised that individualised PEEP with initial RM similarly improves intraoperative oxygenation and EELV in nonobese individuals undergoing robot-assisted prostatectomy.

Methods: Forty males (age, 49e76 yr; BMI <30 kg m^{-2}) undergoing prostatectomy received volume-controlled ventilation (tidal volume 8 ml kg^{-1} predicted body weight). Participants were randomised to either (1) RM followed by individualized PEEP ($RM/PEEP_{IND}$) optimised using electrical impedance tomography or (2) no RM with 5 cm H2O PEEP. The primary outcome was the ratio of arterial oxygen partial pressure to fractional inspired oxygen (PaO2/FiO2) before the last RM before extubation. Secondary outcomes included regional ventilation distribution and EELV which were measured before, during, and after anaesthesia. The cardiovascular effects of $RM/PEEP_{IND}$ were also assessed.

Results: In 20 males randomised to $RM/PEEP_{IND}$, the median $PEEP_{IND}$ was 14 cm H2O [inter-quartile range, 8e20]. The PaO2/ FiO2 was 10.0 kPa higher with $RM/PEEP_{IND}$ before extubation (95% confidence interval [CI], 2.6e17.3 kPa; P¼0.001). $RM/PEEP_{IND}$ increased end-expiratory lung volume by 1.49 L (95% CI, 1.09e1.89 L; P<0.001). $RM/PEEP_{IND}$ also improved the regional ventilation of dependent lung regions. Vasopressor and fluid therapy was similar between groups, although 13 patients randomised to $RM/PEEP_{IND}$ required pharmacological therapy for bradycardia.

Conclusion: In non-obese males, an individualised ventilation strategy improved intraoperative oxygenation, which was associated with higher end-expiratory lung volumes during robot-assisted laparoscopic prostatectomy.

REV	**Piraino T**	**Lung Volume Measurement and Ventilation Distribution During Invasive Mechanical Ventilation**	*Respir Care* ***2020 Jun***

Abstract: Lung volume measurement performed during invasive mechanical ventilation can be used to determine functional residual capacity, changes in end-expiratory lung volume with the application of PEEP, and lung strain. However, many bedside measurements provide useful information without the use of specialized equipment. Ventilation distribution through the lung has traditionally been assessed with computed tomography, but more recently electrical impedance tomography has brought the ability to monitor this at the bedside, and without exposure to radiation. This review will describe techniques to measure lung volumes in the ICU and the relationship between lung strain, stress, and other measurements. This review will also discuss monitoring ventilation distribution at the bedside and the clinical assessment of regional compliance that this technology provides.

CLIN	**Scaramuzzo G, et al.**	**Personalized Positive End-Expiratory Pressure in Acute Respiratory Distress Syndrome: Comparison Between Optimal Distribution of Regional Ventilation and Positive Transpulmonary Pressure**	*Crit Care Med* ***2020 Jun***

Objectives: Different techniques exist to select personalized positive end-expiratory pressure in patients affected by the acute respiratory distress syndrome. The positive end-expiratory transpulmonary pressure strategy aims to counteract dorsal lung collapse, whereas electrical impedance tomography could guide positive end-expiratory pressure selection based on optimal homogeneity of ventilation distribution. We compared the physiologic effects of positive end-expiratory pressure guided by electrical impedance tomography versus transpulmonary pressure in patients affected by acute respiratory distress syndrome.

Design: Cross-over prospective physiologic study.

Setting: Two academic ICUs.

Patients: Twenty ICU patients affected by acute respiratory distress syndrome undergoing mechanical ventilation.

Intervention: Patients monitored by an esophageal catheter and a 32-electrode electrical impedance tomography monitor underwent two positive end-expiratory pressure titration trials by randomized cross-over design to find the level of positive end-expiratory pressure associated with: 1) positive end-expiratory transpulmonary pressure (PEEPPL) and 2) proportion of poorly or nonventilated lung units (Silent Spaces) less than or equal to 15% (PEEPEIT). Each positive end-expiratory pressure level was maintained for 20 minutes, and afterward, lung mechanics, gas exchange, and electrical impedance tomography data were collected.

Measurements and main results: PEEPEIT and PEEPPL differed in all patients, and there was no correlation between the levels identified by the two methods (Rs = 0.25; p = 0.29). PEEPEIT determined a more homogeneous distribution of ventilation with a lower percentage of dependent Silent Spaces (p = 0.02), whereas PEEPPL was characterized by lower airway-but not transpulmonary-driving pressure (p = 0.04). PEEPEIT was significantly higher than PEEPPL in subjects with extrapulmonary acute respiratory distress syndrome (p = 0.006), whereas the opposite was true for pulmonary acute respiratory distress syndrome (p = 0.03).

Conclusions: Personalized positive end-expiratory pressure levels selected by electrical impedance tomography- and transpulmonary pressure-based methods are not correlated at the individual patient level. PEEPPL is associated with lower dynamic stress, whereas PEEPEIT may help to optimize lung recruitment and homogeneity of ventilation. The underlying etiology of acute respiratory distress syndrome could deeply influence results from each method.

CR	**He H, et al.**	**Titration of extra-PEEP against intrinsic-PEEP in severe asthma by electrical impedance tomography**	*Medicine (Baltimore)* ***2020 Jun***

Rationale: The use of extra-positive end-expiratory pressure (PEEP) at a level of 80% intrinsic-PEEP (iPEEP) to improve ventilation in severe asthma patients with control ventilation remains controversial. Electrical impedance tomography (EIT) may provide regional information for determining the optimal extra-PEEP to overcome gas trapping and distribution. Moreover, the experience of using EIT to determine extra-PEEP in severe asthma patients with controlled ventilation is limited.

Patients concerns: A severe asthma patient had 12-cmH2O iPEEP using the end-expiratory airway occlusion method at Zero positive end-expiratory pressures (ZEEP). How to titrate the extra-PEEP to against iPEEP at bedside?

Diagnoses and Interventions: An incremental PEEP titration was performed in the severe asthma patient with mechanical ventilation. An occult pendelluft phenomenon of the ventral and dorsal regions was found during the early and late expiration periods when the extra-PEEP was set to <6 cmH2O. If the extra-PEEP was elevated from 4 to 6 cmH2O, a decrease in the end-expiratory lung impedance (EELI) and a disappearance of the pendelluft phenomenon were observed during the PEEP titration. Moreover, there was broad disagreement as to the “best” extra-PEEP settings according to the various EIT parameters. The regional ventilation delay had the lowest extra-PEEP value (10 cmH2O), whereas the value was 12 cmH2O for the lung collapse/overdistension index and 14 cmH2O for global inhomogeneity.

Outcomes: The extra-PEEP was set at 6 cmH2O, and the severe whistling sound was improved. The patient's condition further became better under the integrated therapy.

Lessons: A broad literature review shows that this was the 3rd case of using EIT to titrate an extra-PEEP to against PEEPi. Importantly, the visualization of occult pendelluft and possible air release during incremental PEEP titration was documented for the first time during incremental PEEP titration in patients with severe asthma. Examining the presence of the occult pendelluft phenomenon and changes in the EELI by EIT might be an alternative means for determining an individual's extra-PEEP.

REV	**Zhao Z, et al.**	**Thoracic electrical impedance tomography in Chinese hospitals: a review of clinical research and daily applications**	*Physiol. Meas* ***2020 May***

Abstract: Chinese scientists and researchers have a long history with electrical impedance tomography (EIT), which can be dated back to the 1980s. No commercial EIT devices for chest imaging were available until the year 2014 when the first device received its approval from the China Food and Drug Administration. Ever since then, clinical research and daily applications have taken place in Chinese hospitals. Up to this date (2019.11) 47 hospitals have been equipped with 50 EIT devices. Twenty-three SCI publications are recorded and a further 21 clinical trials are registered. Thoracic EIT is mainly used in patients before or after surgery, or in intensive care units (ICU). Application fields include the development of strategies for protective lung ventilation (e.g. tidal volume and positive end-expiratory pressure (PEEP) titration, recruitment, choice of ventilation mode and weaning from ventilator), regional lung perfusion monitoring, perioperative monitoring, and potential feedback for rehabilitation. The main challenges for promoting clinical use of EIT are the financial cost and the education of personnel. In this review, the past, present and future of EIT in China are introduced and discussed.

CLIN	**Schumann S, et al.**	**Dependency of respiratory system mechanics on positive endexpiratory pressure and recruitment maneuvers in lung healthy pediatric patients – A randomized crossover study**	*Ped Anaesthesia* ***2020 May***

Background: The lungs of pediatric patients are subjected to tidal derecruitment during mechanical ventilation and in contrast to adult patients this unfavorable condition cannot be resolved with small c increases. This raises the question if higher end-expiratory pressure increases or recruitment maneuvers may resolve tidal derecruitment in pediatric patients.

Aims: We hypothesized that higher PEEP resolves tidal derecruitment in pediatric patients and that recruitment maneuvers between the pressure changes support the improvement of respiratory system mechanics.

Methods: The effects of end-expiratory pressure changes from 3 to 7 cmH2O and vice versa without and with intermediate recruitment maneuvers on respiratory system mechanics and regional ventilation were investigated in 57 mechanically ventilated pediatric patients. The intratidal respiratory system compliance was determined from volume and pressure data before and after PEEP changes and categorized to indicate tidal derecruitment.

Results: Tidal derecruitment occurred comparably frequently at PEEP 3 cmH2O without (13 out of 14 cases) and with recruitment maneuver (14 out of 14 cases) and at PEEP 7 cmH2O without (13 out of 14 cases) and with recruitment maneuver (13 out of 15 cases).

Conclusions: We conclude that contrary to our hypothesis, PEEP up to 7 cmH2O is not sufficient to resolve tidal derecruitment and that recruitment maneuvers may be dispensable in mechanically ventilated pediatric patients.

CR	**He H, et al.**	**Detection of Acute Pulmonary Embolism by Electrical Impedance Tomography and Saline Bolus Injection**	*Am J Respir Crit Care Med* ***2020 May***

Introduction: A 47-year-old woman had sudden dyspnea and hypoxemia after out-of-bed physical activities on the 1st postoperative day (lung cancer resection in upper left lobe). The CT pulmonary angiography suggested multiple embolisms in right pulmonary artery branches (PE, Fig. 1A&B). Electrical impedance tomography (EIT) was applied …

CLIN	**Dall Corte F, et al.**	**Dynamic bedside assessment of the physiologic effects of prone position in acute respiratory distress syndrome patients by electrical impedance tomography**	*Minerva Anestesiol* ***2020 May***

Background: Prone position (PP) improves acute respiratory distress syndrome (ARDS) survival by reducing the risk of ventilation-induced lung injury. However, inter-individual variability is a hallmark of ARDS and lung protection by PP might not be optimal in all patients. In the present study, we dynamically assessed physiologic effects of PP by electrical impedance tomography (EIT) and identified predictors of improved lung protection by PP in ARDS patients.

Methods: Prospective physiologic study on 16 intubated, sedated and paralyzed patients with ARDS undergoing PP as per clinical decision. EIT data were recorded during two consecutive steps: 1) baseline supine position before and after a recruitment maneuver (RM); 2) prone position before and after a RM. "Improved lung protection" by PP was defined in the presence of simultaneous improvement of ventilation homogeneity (Hom), alveolar overdistension and collapse (ODCL) and amount of recruitable lung volume by RM in comparison to supine.

Results: PP versus supine increased the tidal volume distending the dependent regions (Vt<inf>dep</inf>), resulting in improved Hom (1.1±0.9 vs. 1.7±0.9, P=0.021). PP also reduced ODCL (19±9% vs. 28±8%, P=0.005) and increased the recruitable lung volume (80 [71-157] vs. 59 [1-110] mL, P=0.025). "Improved lung protection" by PP was predicted by lower Vt<inf>dep</inf>, higher Vt<inf>ndep</inf> and poorer Hom measured during baseline supine position (P<0.05).

Conclusions: EIT enables dynamic bedside assessment of the physiologic effects of PP and might support early recognition of ARDS patients more likely to benefit from PP.

ES	**Muders T, et al.**	**Individualized Positive End-expiratory Pressure and Regional Gas Exchange in Porcine Lung Injury**	*Anesthesiology* ***2020 Apr***

Background: In acute respiratory failure elevated intraabdominal pressure aggravates lung collapse, tidal recruitment, and ventilation inhomogeneity. Low positive end-expiratory pressure (PEEP) may promote lung collapse and intrapulmonary shunting, whereas high PEEP may increase dead space by inspiratory overdistension. The authors hypothesized that an electrical impedance tomography-guided PEEP approach minimizing tidal recruitment improves regional ventilation and perfusion matching when compared to a table-based low PEEP/no recruitment and an oxygenation-guided high PEEP/full recruitment strategy in a hybrid model of lung injury and elevated intraabdominal pressure.

Methods: In 15 pigs with oleic acid-induced lung injury intraabdominal pressure was increased by intraabdominal saline infusion. PEEP was set in randomized order: (1) guided by a PEEP/inspired oxygen fraction table, without recruitment maneuver; (2) minimizing tidal recruitment guided by electrical impedance tomography after a recruitment maneuver; and (3) maximizing oxygenation after a recruitment maneuver. Single photon emission computed tomography was used to analyze regional ventilation, perfusion, and aeration. Primary outcome measures were differences in PEEP levels and regional ventilation/perfusion matching.

Results: Resulting PEEP levels were different (mean ± SD) with (1) table PEEP: 11 ± 3 cm H2O; (2) minimal tidal recruitment PEEP: 22 ± 3 cm H2O; and (3) maximal oxygenation PEEP: 25 ± 4 cm H2O; $P < 0.001$. Table PEEP without recruitment maneuver caused highest lung collapse (28 ± 11% vs. 5 ± 5% vs. 4 ± 4%; $P < 0.001$), shunt perfusion (3.2 ± 0.8 l/min vs. 1.0 ± 0.8 l/min vs. 0.7 ± 0.6 l/min; $P < 0.001$) and dead space ventilation (2.9 ± 1.0 l/min vs. 1.5 ± 0.7 l/min vs. 1.7 ± 0.8 l/min; $P < 0.001$). Although resulting in different PEEP levels, minimal tidal recruitment and maximal oxygenation PEEP, both following a recruitment maneuver, had similar effects on regional ventilation/perfusion matching.

Conclusions: When compared to table PEEP without a recruitment maneuver, both minimal tidal recruitment PEEP and maximal oxygenation PEEP following a recruitment maneuver decreased shunting and dead space ventilation, and the effects of minimal tidal recruitment PEEP and maximal oxygenation PEEP were comparable.

CLIN	**Mauri T, et al.**	**Potential for Lung Recruitment and Ventilation-Perfusion Mismatch in Patients With the Acute Respiratory Distress Syndrome From Coronavirus Disease 2019**	*Crit Care Med* ***2020 Apr***

Objectives: Severe cases of coronavirus disease 2019 develop the acute respiratory distress syndrome, requiring admission to the ICU. This study aimed to describe specific pathophysiological characteristics of acute respiratory distress syndrome from coronavirus disease 2019.

Design: Prospective crossover physiologic study.

Setting: ICU of a university-affiliated hospital from northern Italy dedicated to care of patients with confirmed diagnosis of coronavirus disease 2019.

Patients: Ten intubated patients with acute respiratory distress syndrome and confirmed diagnosis of coronavirus disease 2019.

Interventions: We performed a two-step positive end-expiratory pressure trial with change of 10 cm H2O in random order.

Measurements and main results: At each positive end-expiratory pressure level, we assessed arterial blood gases, respiratory mechanics, ventilation inhomogeneity, and potential for lung recruitment by electrical impedance tomography. Potential for lung recruitment was assessed by the recently described recruitment to inflation ratio. In a subgroup of seven paralyzed patients, we also measured ventilation-perfusion mismatch at lower positive end-expiratory pressure by electrical impedance tomography. At higher positive end-expiratory pressure, respiratory mechanics did not change significantly: compliance remained relatively high with low driving pressure. Oxygenation and ventilation inhomogeneity improved but arterial CO2 increased despite unchanged respiratory rate and tidal volume. The recruitment to inflation ratio presented median value higher than previously reported in acute respiratory distress syndrome patients but with large variability (median, 0.79 [0.53-1.08]; range, 0.16-1.40). The FIO2 needed to obtain viable oxygenation at lower positive end-expiratory pressure was significantly correlated with the recruitment to inflation ratio (r = 0.603; p = 0.05). The ventilation-perfusion mismatch was elevated (median, 34% [32-45%] of lung units) and, in six out of seven patients, ventilated nonperfused units represented a much larger proportion than perfused nonventilated ones.

Conclusions: In patients with acute respiratory distress syndrome from coronavirus disease 2019, potential for lung recruitment presents large variability, while elevated dead space fraction may be a specific pathophysiological trait. These findings may guide selection of personalized mechanical ventilation settings.

CLIN	**Coppadoro A, et al.**	**Occurrence of pendelluft under pressure support ventilation in patients who failed a spontaneous breathing trial: an observational study**	*Ann. Intensive Care* ***2020 Apr***

Background: Pendelluft, the movement of gas within different lung regions, is present in animal models of assisted mechanical ventilation and associated with lung overstretching. Due to rebreathing of CO2 as compared to fresh gas, pendelluft might reduce ventilatory efficiency possibly exacerbating patient's respiratory workload during weaning. Our aim was to measure pendelluft by electrical impedance tomography (EIT) in patients who failed a spontaneous breathing trial (SBT).

Methods: This is an observational study conducted in a general intensive care unit of a tertiary-level teaching hospital. EIT signal was recorded in 20 patients while pressure support (PS) ventilation was progressively reduced from clinical level (baseline) to 2 cmH2O, as in an SBT; four ventral-to-dorsal lung regions of interest were identified for pendelluft measurement. A regional gas movement (> 6 mL) occurring in a direction opposite to the global EIT signal was considered diagnostic for high pendelluft.

Results: Eight patients out of 20 (40%) were classified as high-pendelluft; baseline clinical characteristics did not differ between high- and low-pendelluft patients. At PS reduction, pendelluft and EtCO2 increased more in the high-pendelluft group ($p < .001$ and .011, respectively). The volume of gas subject to pendelluft moved almost completely from the ventral towards the dorsal lung regions, while the opposite movement was minimal (16.3 [10:32.8] vs. 0 [0:1.8] mL, $p = .001$). In a subgroup of patients, increased pendelluft volumes positively correlated with markers of respiratory distress such as increased respiratory rate, p0.1, and EtCO2.

Conclusions: Occult pendelluft can be measured by EIT, and is frequently present in patients failing an SBT. When present, pendelluft increases with the reduction of ventilator support and is associated with increased EtCO2, suggesting a reduction of the ability to eliminate CO2.

	Zhang R, et al.	**Effect of postextubation high-flow nasal cannula therapy on lung recruitment and overdistension in high-risk patient**	*Crit Care* ***2020 Mar***

Background: Postextubation high-flow nasal cannula (HFNC) is used as a support therapy in high-risk patients in ICU. This study aimed to determine the effects of HFNC therapy on lung recruitment and overdistension assessed by electrical impedance tomography (EIT).

Methods: Twenty-four patients who received HFNC within 24 h after extubation were prospectively enrolled in this study. EIT was used to monitor regional lung ventilation distributions at baseline (conventional oxygen therapy) and three flow rate levels of HFNC therapy (20, 40, and 60 L/min). Change of end-expiratory lung impedance (ΔEELI), regional recruitment (recruited-pixels) and overdistension (overdistended-pixels), and lung strain change were determined by EIT. EIT images were equally divided into four ventral-to-dorsal horizontal regions of interest (ROIs 1, 2, 3, and 4). "Overdistension-by HFNC" due to HFNC is defined as an increase of overdistened-pixels > 10 than baseline. Patients were divided into two groups: (1) high potential of recruitment (HPR), recruited-pixels > 10 pixels at 60 L/min than baseline, and (2) low potential of recruitment (LPR), recruited-pixels < 10 pixels at 60 L/min than baseline.

Results: When the flow rate gradually increased from baseline to 60 L/min, a significant and consistent increasing trend of global ΔEELI (%) ($p < 0.0001$), recruited-pixels ($p < 0.001$), and overdistended-pixels ($p = 0.101$) was observed. Moreover, the increase of ΔEELI was mainly distributed in ROI2 ($p = 0.001$) and ROI3 ($p < 0.0001$). The HPR group (13/24 patients) had significantly higher recruited-pixels than the LPR group (11/24 patients) at 20, 40, and 60 L/min. There were no significant differences in PaO2/FiO2, ΔEELI (%), and overdistention pixels between the two groups. The HPR group had 13 patients in which no one had "overdistension-by HFNC", and the LPR group had 11 patients in which 4 patients had "overdistension-by HFNC" (0/13 vs. 4/11, $p = 0.017$).

Conclusions: Using EIT could identify diverse effects of HFNC on lung regional ventilation in postextubation situations. Further study is required to validate using "HFNC effect" based on lung recruitment and overdistension by EIT in clinical practice.

ES	**Wang Y-M, et al.**	**Use of Electrical Impedance Tomography (EIT) to Estimate Global and Regional Lung Recruitment Volume (VREC) Induced by Positive End-Expiratory Pressure (PEEP): An Experiment in Pigs with Lung Injury**	*Med Sci Monit* ***2020 Mar***

Background: Electrical impedance tomography (EIT) is a real-time tool used to monitor lung volume change at the bedside, which could be used to measure lung recruitment volume (VREC) for setting positive end-expiratory pressure (PEEP). We assessed and compared the agreement in VREC measurement with the EIT method versus the flow-derived method.

Material and Methods: In 12 Bama pigs, lung injury was induced by tracheal instillation of hydrochloric acid and verified by an arterial partial pressure of oxygen to inspired oxygen fraction ratio below 200 mmHg. During the end-expiratory occlusion, an airway release maneuver was conduct at 5 and 15 cmH_2O of PEEP. VREC was measured by flow-integrated PEEP-induced lung volume change (flow-derived method) and end-expiratory lung impedance change (EIT-derived method). Linear regression and Bland-Altman analysis were used to test the correlation and agreement between these 2 measures.

Results: Lung injury was successfully induced in all the animals. EIT-derived VREC was significantly correlated with flow-derived VREC (R^2=0.650, p=0.002). The bias (the lower and upper limits of agreement) was -19 (-182 to 144) ml. The median (interquartile range) of EIT-derived VREC was 322 (218-469) ml, with 110 (59-142) ml and 194 (157-307) ml in dependent and nondependent lung regions, respectively. Global and regional respiratory system compliance increased significantly at high PEEP compared to those at low PEEP.

Conclusions: Close correlation and agreement were found between EIT-derived and flow-derived VREC measurements. The advantages of EIT-derived recruitability assessment included the avoidance of ventilation interruption and the ability to provide regional recruitment information.

ES	**Scaramuzzo G, et al.**	**Influence of Positive End-Expiratory Pressure Titration on the Effects of Pronation in Acute Respiratory Distress Syndrome: A Comprehensive Experimental Study**	*Front. Physiol* ***2020 Mar***

Abstract: Prone position can reduce mortality in acute respiratory distress syndrome (ARDS), but several studies found variable effects on oxygenation and lung mechanics. It is unclear whether different positive end-expiratory pressure (PEEP) titration techniques modify the effect of prone position. We tested, in an animal model of ARDS, if the PEEP titration method may influence the effect of prone position on oxygenation and lung protection. In a crossover study in 10 piglets with a two-hit injury ARDS model, we set the “best PEEP” according to the ARDS Network low-PEEP table (BPARDS) or targeting the lowest transpulmonary driving pressure (BPDPL). We measured gas exchange, lung mechanics, aeration, ventilation, and perfusion with computed tomography (CT) and electrical impedance tomography in each position with both PEEP titration techniques. The primary endpoint was the PaO2/FiO2 ratio. Secondary outcomes were lung mechanics, regional distribution of ventilation, regional distribution of perfusion, and homogeneity of strain derived by CT scan. The PaO2/FiO2 ratio increased in prone position when PEEP was set with BPARDS [difference 54 (19–106) mmHg, p = 0.04] but not with BPDPL [difference 17 (−24 to 68) mmHg, p = 0.99]. The transpulmonary driving pressure significantly decreased during prone position with both BPARDS [difference −0.9 (−1.5 to −0.9) cmH2O, p = 0.009] and BPDPL [difference −0.55 (−1.6 to −0.4) cmH2O, p = 0.04]. Pronation homogenized lung regional strain and ventilation and redistributed the ventilation/perfusion ratio along the sternal-to-vertebral gradient. The PEEP titration technique influences the oxygenation response to prone position. However, the lung-protective effects of prone position could be independent of the PEEP titration strategy.

ES	**Liu S, et al.**	**Optimal mean airway pressure during high-frequency oscillatory ventilation in an experimental model of acute respiratory distress syndrome: EIT-based method**	*Ann Intensive Care* ***2020 Mar***

Background: High-frequency oscillatory ventilation (HFOV) may theoretically provide lung protective ventilation. The negative clinical results may be due to inadequate mean airway pressure (mPaw) settings in HFOV. Our objective was to evaluate the air distribution, ventilatory and hemodynamic effects of individual mPaw titration during HFOV in ARDS animal based on oxygenation and electrical impedance tomography (EIT).

Methods: ARDS was introduced with repeated bronchoalveolar lavage followed by injurious mechanical ventilation in ten healthy male pigs (51.2 ± 1.9 kg). Settings of HFOV were 9 Hz (respiratory frequency), 33% (inspiratory time) and 70 cmH2O (Δpressure). After lung recruitment, the mPaw was reduced in steps of 3 cmH2O every 6 min. Hemodynamics and blood gases were obtained in each step. Regional ventilation distribution was determined with EIT.

Results: PaO2/FiO2 decreased significantly during the mPaw decremental phase ($p < 0.001$). Lung overdistended regions decreased, while recruitable regions increased as mPaw decreased. The optimal mPaw with respect to PaO2/FiO2 was 21 (18.0–21.0) cmH2O, that is comparable to EIT-based center of ventilation (EIT-CoV) and EIT-collapse/over, 19.5 (15.0–21.0) and 19.5 (18.0–21.8), respectively ($p = 0.07$). EIT-CoV decreasing along with mPaw decrease revealed redistribution toward non-dependent regions. The individual mPaw titrated by EIT-based indices improved regional ventilation distribution with respect to overdistension and collapse ($p = 0.035$).

Conclusion: Our data suggested personalized optimal mPaw titration by EIT-based indices improves regional ventilation distribution and lung homogeneity during high-frequency oscillatory ventilation.

EDIT	**Nishimura M**	**Electrical Impedance Tomography: The Promise of Noninvasive Lung Images at the Bedside**	*Respir Care* ***2020 Mar***

Introduction:
Medical technology has been developing faster than many clinicians ever envisioned. One clear example is the revolution in the field of medical imaging. Early in development, it took time to get computed tomography (CT) images, and CT was less than ideal for the lungs because of respiratory movement. While lung images were taken, breath-holding was essential even in patients with respiratory failure. Now dynamic CT images are available.

CLIN	**Weber J, et al.**	**Effect of individualized PEEP titration guided by intratidal compliance profile analysis on regional ventilation assessed by electrical impedance tomography – a randomized controlled trial**	*BMC Anesthesiology* ***2020 Feb***

Background: The application of positive end-expiratory pressure (PEEP) may reduce dynamic strain during mechanical ventilation. Although numerous approaches for PEEP titration have been proposed, there is no accepted strategy for titrating optimal PEEP. By analyzing intratidal compliance profiles, PEEP may be individually titrated for patients.

Methods: After obtaining informed consent, 60 consecutive patients undergoing general anesthesia were randomly allocated to mechanical ventilation with PEEP 5 cmH2O (control group) or PEEP individually titrated, guided by an analysis of the intratidal compliance profile (intervention group). The primary endpoint was the frequency of each nonlinear intratidal compliance (CRS) profile of the respiratory system (horizontal, increasing, decreasing, and mixed). The secondary endpoints measured were respiratory mechanics, hemodynamic variables, and regional ventilation, which was assessed via electrical impedance tomography.

Results: The frequencies of the CRS profiles were comparable between the groups. Besides PEEP [control: 5.0 (0.0), intervention: 5.8 (1.1) cmH2O, $p < 0.001$], the respiratory and hemodynamic variables were comparable between the two groups. The compliance profile analysis showed no significant differences between the two groups. The loss of ventral and dorsal regional ventilation was higher in the control [ventral: 41.0 (16.3)%; dorsal: 25.9 (13.8)%] than in the intervention group [ventral: 29.3 (17.6)%; dorsal: 16.4 (12.7)%; p (ventral) = 0.039, p (dorsal) = 0.028].

Conclusions: Unfavorable compliance profiles indicating tidal derecruitment were found less often than in earlier studies. Individualized PEEP titration resulted in slightly higher PEEP. A slight global increase in aeration associated with this was indicated by regional gain and loss analysis. Differences in dorsal to ventral ventilation distribution were not found.

CLIN	**Franchineau G , et al.**	**Prone positioning monitored by electrical impedance tomography in patients with severe acute respiratory distress syndrome on veno-venous ECMO**	*Ann Intensive Care* ***2020 Feb***

Background: Prone positioning (PP) during veno-venous ECMO is feasible, but its physiological effects have never been thoroughly evaluated. Our objectives were to describe, through electrical impedance tomography (EIT), the impact of PP on global and regional ventilation, and optimal PEEP level.

Methods: A monocentric study conducted on ECMO-supported severe ARDS patients, ventilated in pressure-controlled mode, with 14-cmH2O driving pressure and EIT-based “optimal PEEP”. Before, during and after a 16-h PP session, EIT-based distribution and variation of tidal impedance, VTdorsal/VTglobal ratio, end-expiratory lung impedance (EELI) and static compliance were collected. Subgroup analyses were performed in patients who increased their static compliance by ≥ 3 mL/cmH2O after 16 h of PP.

Results: For all patients (n = 21), tidal volume and EELI were redistributed from ventral to dorsal regions during PP. EIT-based optimal PEEP was significantly lower in PP than in supine position. Median (IQR) optimal PEEP decreased from 14 (12–16) to 10 (8–14) cmH2O. Thirteen (62%) patients increased their static compliance by ≥ 3 mL/cmH2O after PP on ECMO. This subgroup had higher body mass index, more frequent viral pneumonia, shorter ECMO duration, and lower baseline VTdorsal/VTglobal ratio than patients with compliance ≤ 3 mL/cmH2O ($P < 0.01$).

Conclusion: Although baseline tidal volume distribution on EIT may predict static compliance improvement after PP on ECMO, our results support physiological benefits of PP in all ECMO patients, by modifying lung mechanics and potentially reducing VILI. Further studies, including a randomized–controlled trial, are now warranted to confirm potential PP benefits during ECMO.

CLIN	**Inany HS, et al.**	**Distribution of Ventilation Measured by Electrical Impedance Tomography in Critically Ill Children**	*Respir Care* ***2020 Jan***

Background: Electrical impedance tomography (EIT) is a noninvasive, portable lung imaging technique that provides functional distribution of ventilation. We aimed to describe the relationship between the distribution of ventilation by mode of ventilation and level of oxygenation impairment in children who are critically ill. We also aimed to describe the safety of EIT application.

Methods: A prospective observational study of EIT images obtained from subjects in the pediatric ICU. Images were categorized by whether the subjects were on intermittent mandatory ventilation (IMV), continuous spontaneous ventilation, or no positive-pressure ventilation. Images were categorized by the level of oxygenation impairment when using [Formula: see text]/[Formula: see text]. Distribution of ventilation is described by the center of ventilation.

Results: Sixty-four images were obtained from 25 subjects. Forty-two images obtained during IMV with a mean ± SD center of ventilation of 55 ± 6%, 14 images during continuous spontaneous ventilation with a mean ± SD center of ventilation of 48.1 ± 11%, and 8 images during no positive-pressure ventilation with a mean ± SD center of ventilation of 47.5 ± 10%. Seventeen images obtained from subjects with moderate oxygenation impairment with a mean ± SD center of ventilation of 59.3 ± 1.9%, 12 with mild oxygenation impairment with a mean ± SD center of ventilation of 52.6 ± 2.3%, and 4 without oxygenation impairment with a mean ± SD center of ventilation of 48.3 ± 4%. There was more ventral distribution of ventilation with IMV versus continuous spontaneous ventilation (P = .009), with IMV versus no positive-pressure ventilation (P = .01) cohorts, and with moderate oxygenation impairment versus cohorts without oxygenation impairment (P = .009). There were no adverse events related to the placement and use of EIT in our study.

Conclusions: Children who had worse oxygen impairment or who received controlled modes of ventilation had more ventral distribution of ventilation than those without oxygen impairment or the subjects who were spontaneously breathing. The ability of EIT to detect changes in the distribution of ventilation in real time may allow for distribution-targeted mechanical ventilation strategies to be deployed proactively; however, future studies are needed to determine the effectiveness of such a strategy.

EDIT	**Davies P, Silvestre C**	**Electrical impedance tomography in clinical use: Unnecessary technology or a unique angle in respiratory monitoring?**	*Pediatr Pulmonol* ***2020 Jan***

Introduction:
Hough and colleagues reported on their experience of using electrical impedance tomography (EIT) in the clinical assessment of a patient with a very rare intrathoracic tumor1 in this journal. What does EIT bring to respiratory assessment? Is it an unnecessary additional piece of technology, or a respiratory monitoring tool that gives dimensions of knowledge hitherto unknown? …

CLIN	**Guérin C, et al.**	**Low-pressure support vs automatic tube compensation during spontaneous breathing trial for weaning**	*Ann Intensive Care* ***2019 Dec***

Background: During spontaneous breathing trial, low-pressure support is thought to compensate for endotracheal tube resistance, but it actually should provide overassistance. Automatic tube compensation is an option available in the ventilator to compensate for flow-resistance of endotracheal tube. Its effects on patient effort have been poorly investigated. We aimed to compare the effects of low-pressure support and automatic tube compensation during spontaneous breathing trial on breathing power and lung ventilation distribution.

Results: We performed a randomized crossover study in 20 patients ready to wean. Each patient received both methods for 30 min separated by baseline ventilation: pressure support 0 cmH2O and automatic tube compensation 100% in one period and pressure support 7 cmH2O without automatic tube compensation in the other period, a 4 cmH2O positive end-expiratory pressure being applied in each. Same ventilator brand (Evita XL, Draeger, Germany) was used. Breathing power was assessed from Campbell diagram with esophageal pressure, airway pressure, flow and volume recorded by a data logger. Lung ventilation distribution was assessed by using electrical impedance tomography (Pulmovista, Draeger, Germany). During the last 2 min of low-pressure support and automatic compensation period breathing power and lung ventilation distribution were measured on each breath. Breathing power generated by the patient's respiratory muscles was 7.2 (4.4–9.6) and 9.7 (5.7–21.9) J/min in low-pressure support and automatic tube compensation periods, respectively (P = 0.011). Lung ventilation distribution was not different between the two methods.

Conclusions: We found that ATC was associated with higher breathing power than low PS during SBT without altering the distribution of lung ventilation.