Literature List
Electrical Impedance Tomography

2021

Electrical Impedance Tomography (EIT)
Literature List 2021

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Categories

CLIN = Clinical Study

ES = Experimental Study

REV = Review

CR = Case Report

EDIT = Editorial

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CLIN	Li J et al.	**Electrical Impedance Tomography Predicts Weaning Success in Adult Patients With Delayed Upper Abdominal Surgery: A Single-Center Retrospective Study**	*Front Med 2021 Dec*

Objective: To evaluate the predictive value of electrical impedance tomography (EIT) in patients with delayed ventilator withdrawal after upper abdominal surgery.

Methods: We retrospectively analyzed data of patients who were ventilated >24 h after upper abdominal surgery between January 2018 and August 2019. The patients were divided into successful (group S) and failed (group F) weaning groups. EIT recordings were obtained at 0, 5, 15, and 30 min of spontaneous breathing trials (SBTs) with SBT at 0 min set as baseline. We assessed the change in delta end-expiratory lung impedance and tidal volume ratio ($\Delta EELI/V_T$) from baseline, the change in compliance change percentage variation ($|\Delta(C_W-C_L)|$) from baseline, the standard deviation of regional ventilation delay index (RVD_{SD}), and global inhomogeneity (GI) using generalized estimation equation analyses. Receiver operating characteristic curve analyses were performed to evaluate the predictive value of parameters indicating weaning success.

Results: Among the 32 included patients, ventilation weaning was successful in 23 patients but failed in nine. Generalized estimation equation analysis showed that compared with group F, the $\Delta EELI/V_T$ was lower, and the GI, RVDSD, and ($|\Delta(C_W-C_L)|$) were higher in group S. For predicting withdrawal failure, the areas under the curve of the ΔEELI/VT, ($|\Delta(C_W-C_L)|$), and the RVDSD were 0.819, 0.918, and 0.918, and 0.816, 0.884, and 0.918 at 15 and 30 min during the SBTs, respectively.

Conclusion: The electrical impedance tomography may predict the success rate of ventilator weaning in patients with delayed ventilator withdrawal after upper abdominal surgery.

CLIN	Frerichs I et al.	**Spatial Ventilation Inhomogeneity Determined by Electrical Impedance Tomography in Patients With Chronic Obstructive Lung Disease**	*Front Physiol 13 2021 Dec*

Abstract: The aim of this study was to examine whether electrical impedance tomography (EIT) could determine the presence of ventilation inhomogeneity in patients with chronic obstructive lung disease (COPD) from measurements carried out not only during conventional forced full expiration maneuvers but also from forced inspiration maneuvers and quiet tidal breathing and whether the inhomogeneity levels were comparable among the phases and higher than in healthy subjects. EIT data were acquired in 52 patients with exacerbated COPD (11 women, 41 men, 68 ± 11 years) and 14 healthy subjects (6 women, 8 men, 38 ± 8 years). Regional lung function parameters of forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), forced inspiratory vital capacity (FIVC), forced inspiratory volume in 1 s (FIV_1), and tidal volume (V_T) were determined in 912 image pixels. The spatial inhomogeneity of the pixel parameters was characterized by the coefficients of variation (CV) and the global inhomogeneity (GI) index. CV and GI values of pixel FVC, FEV_1, FIVC, FIV_1, and V_T were significantly higher in patients than in healthy subjects ($p \leq 0.0001$). The ventilation distribution was affected by the analyzed lung function parameter in patients (CV: $p = 0.0024$, GI: $p = 0.006$) but not in healthy subjects. Receiver operating characteristic curves showed that CV and GI discriminated patients from healthy subjects with an area under the curve (AUC) of 0.835 and 0.852 (FVC), 0.845 and 0.867 (FEV_1), 0.903 and 0.903 (FIVC), 0.891 and 0.882 (FIV_1), and 0.821 and 0.843 (V_T), respectively. These findings confirm the ability of EIT to identify increased ventilation inhomogeneity in patients with COPD.

CLIN	Yuan S et al.	**Effect of Position Change From the Bed to a Wheelchair on the Regional Ventilation Distribution Assessed by Electrical Impedance Tomography in Patients With Respiratory Failure**	*Front Med* **2021 Nov**

Background: There is limited knowledge about the effect of position change on regional lung ventilation in patients with respiratory failure. This study aimed to examine the physiological alteration of regional lung ventilation during the position change from lying in bed to sitting on a wheelchair.

Methods: In this study, 41 patients with respiratory failure who were weaned from the ventilators were prospectively enrolled. The electrical impedance tomography (EIT) was used to assess the regional lung ventilation distribution at four time points (Tbase: baseline, supine position in the bed, T30min: sitting position in the wheelchair after 30 min, T60min: sitting position in the wheelchair after 60 min, Treturn: the same supine position in the bed after position changing). The EIT-based global inhomogeneity (GI) and center of ventilation (CoV) indices were calculated. The EIT images were equally divided into four ventral-to-dorsal horizontal regions of interest (ROIs 1–4). Depending on the improvement in ventilation distribution in the dependent regions at T60min (threshold set to 15%), the patients were divided into the dorsal ventilation improved (DVI) and not improved (non-DVI) groups.

Results: When the patients moved from the bed to a wheelchair, there was a significant and continuous increase in ventilation in the dorsal regions (ROI 3 + 4: 45.9 ± 12.1, 48.7 ± 11.6, 49.9 ± 12.6, 48.8 ± 10.6 for Tbase, T30min, T60min, and Treturn, respectively; $p = 0.015$) and CoV (48.2 ± 10.1, 50.1 ± 9.2, 50.5 ± 9.6, and 49.5 ± 8.6, $p = 0.047$). In addition, there was a significant decrease in GI at T60min compared with Tbase. The DVI group (n = 18) had significantly higher oxygenation levels than the non-DVI group (n = 23) after position changing. ROI4Tbase was significantly negatively correlated with the ΔSpO_2 ($R = 0.72$, $p < 0.001$). Using a cutoff value of 6.5%, ROI4Tbase had 79.2% specificity and 58.8% sensitivity in indicating the increase in the dorsal region related to the position change. The corresponding area under the curve (AUC) was 0.806 (95% CI, 0.677–0.936).

Conclusion: Position change may improve the ventilation distribution in the study patients. The EIT can visualize real-time changes of the regional lung ventilation at the bedside to guide the body position change of the patients in the intensive care unit (ICU) and measure the effect of clinical practice.

CLIN	Su PL et al.	**Effect of Position Change From the Bed to a Wheelchair on the Regional Ventilation Distribution Assessed by Electrical Impedance Tomography in Patients With Respiratory Failure**	*J. Med. Biol. Eng. 41* **2021 Nov**

Purpose: The positive end-expiratory pressure (PEEP) level with best respiratory system compliance (C_{rs}) is frequently used for PEEP selection in acute respiratory distress syndrome (ARDS) patients. On occasion, two similar best C_{rs} (where the difference between the C_{rs} of two PEEP levels is < 1 ml/cm H_2O) may be identified during decremental PEEP titration. Selecting PEEP under such conditions is challenging. The aim of this study was to provide supplementary rationale for PEEP selection by assessing the global and regional ventilation distributions between two PEEP levels in this situation.

Methods: Eight ARDS cases with similar best C_{rs} at two different PEEP levels were analyzed using examination-specific electrical impedance tomography (EIT) measures and airway stress index (SI_{aw}). Five C_{rs} were measured at PEEP values of 25 cm H2O ($PEEP_{25}$), 20 cm H2O ($PEEP_{20}$), 15 cm H2O ($PEEP_H$), 11 cm H2O ($PEEP_I$), and 7 cm H2O (PEEPL). The higher PEEP value of the two PEEPs with similar best C_{rs} was designated as $PEEP_{upper}$, while the lower designated as $PEEP_{lower}$.

Results: PEEPH and PEEPI shared the best C_{rs} in two cases, while similar C_{rs} was found at $PEEP_I$ and $PEEP_L$ in the remaining six cases. SI_{aw} was higher with $PEEP_{upper}$ as compared to $PEEP_{lower}$ (1.06 ± 0.10 versus 0.99 ± 0.09, $p = 0.05$). Proportion of lung hyperdistension was significantly higher with $PEEP_{upper}$ than $PEEP_{lower}$ (7.0 ± 5.1% versus 0.3 ± 0.5%, $p = 0.0002$). In contrast, proportion of recruitable lung collapse was higher with $PEEP_{lower}$ than $PEEP_{upper}$ (18.6 ± 4.4% versus 5.9 ± 3.7%, $p < 0.0001$). Cyclic alveolar collapse and reopening during tidal breathing was higher at $PEEP_{lower}$ than $PEEP_{upper}$ (34.4 ± 19.3% versus 16.0 ± 9.1%, $p = 0.046$). The intratidal gas distribution (ITV) index was also significantly higher at $PEEP_{lower}$ than $PEEP_{upper}$ (2.6 ± 1.3 versus 1.8 ± 0.7, $p = 0.042$).

Conclusions: $PEEP_{upper}$ is a rational selection in ARDS cases with two similar best C_{rs}. EIT provides additional information for the selection of PEEP in such circumstances.

CLIN	**Nascimento MS et al.**	**Electrical impedance tomography in pediatric patients with COVID-19, the first reports**	*BMC Pulm Med* **2021 Nov**
Background: Electrical impedance tomography (EIT) is a noninvasive, radiation-free, bedside tool to monitor ventilation distribution in real time. **Objective:** To evaluate, in pediatric COVID-19 patients, the ventilation distribution using EIT and compare it to thoracic computed tomography (TCT) or chest radiograph results obtained in these patients. **Methods:** This was a prospective, observational clinical study including pediatric patients admitted to the intensive care unit of a private hospital. The patients monitored with EIT tested positive for COVID-19 and were submitted to the previously mentioned radiation exams. EIT monitoring lasted 15 min and no sedation was used. **Results:** Six patients were included in this study. The main differences observed in the EIT were in the right-left distribution and were compatible with the morphological changes found in the TCT or radiograph images due to COVID-19 infection. **Conclusion:** We conclude that EIT is ready to investigate the ventilatory profile present at different lung diseases, including COVID-19, and might postpone or mitigate the need of repeated ionizing radiation exams in the pediatric population, although larger pediatric cohorts comparing to standard radiological imaging are needed.			
CR	**Guglielmo RD, Khemani RG**	**Tracheobronchial Foreign Body Aspiration Diagnosed with Electrical Impedance Tomography**	*Case Reports in Pediatrics* **2021 Nov**
Abstract: Foreign body aspiration (FBA) in children has a high morbidity, and early diagnosis is the key for preventing acute and chronic respiratory complications. To diagnose FBA, commonly used imaging modalities have limited negative predictive value, and rigid bronchoscopy remains as the gold standard. We present a case where the diagnosis of FBA was made in a novel way with electrical impedance tomography (EIT). Case Presentation. A 19-month-old previously healthy boy was admitted with a clinical diagnosis of respiratory failure secondary to bronchiolitis. Chest X-ray showed bilateral lung hyperinflation. He enrolled in a research study which used EIT to measure the effects of high flow nasal cannula (HFNC) on minute ventilation in children with bronchiolitis. On initiation, the patient had near-normal right lung ventilation (98%) and near-absent left lung ventilation (2%). We discontinued the study and alerted the medical team that we suspected FBA. Further imaging (lateral decubitus films and lung ultrasounds) was also obtained, but was not diagnostic. Rigid bronchoscopy was performed and showed a peanut occluding the left mainstem bronchus (LMB). The peanut was removed followed by complete resolution of the patient's symptoms. Conclusions. We believe this is the first reported case of FBA diagnosed via EIT. EIT has been shown to be a useful but underutilized technology for diagnosing respiratory disease. While FBA remains a relatively common cause of morbidity and mortality in children less than age four, early diagnosis remains difficult and requires vigilance. This case illustrates the challenges of relying on chest films and ultrasound to assist with diagnosis and suggests that EIT in combination with a thorough history and physical exam can be used to confirm the presence of FBA.			

REV	Xu M, He H, Yun Long Y	**Lung Perfusion Assessment by Bedside Electrical Impedance Tomography in Critically Ill Patients**	*Front Physiol* ***2021 Oct***

Abstract: As a portable, radiation-free imaging modality, electrical impedance tomography (EIT) technology has shown promise in the bedside visual assessment of lung perfusion distribution in critically ill patients. The two main methods of EIT for assessing lung perfusion are the pulsatility and conductivity contrast (saline) bolus method. Increasing attention is being paid to the saline bolus EIT method in the evaluation of regional pulmonary perfusion in clinical practice. This study seeks to provide an overview of experimental and clinical studies with the aim of clarifying the progress made in the use of the saline bolus EIT method. Animal studies revealed that the saline bolus EIT method presented good consistency with single-photon emission CT (SPECT) in the evaluation of lung regional perfusion changes in various pathological conditions. Moreover, the saline bolus EIT method has been applied to assess the lung perfusion in a pulmonary embolism and the effect of positive end-expiratory pressure (PEEP) on regional ventilation/perfusion ratio (V/Q) and acute respiratory distress syndrome (ARDS) in several clinical studies. The implementation of saline boluses, data analyses, precision, and cutoff values varied among different studies, and a consensus must be reached regarding the clinical application of the saline bolus EIT method. Further study is required to validate the impact of the described saline bolus EIT method on decision-making, therapeutic management, and outcomes in critically ill patients.

CLIN	Wang G et al.	**The Application of Electrical Impedance Tomography During the Ventilator Weaning Process**	*Int J Gen Med* ***2021 Oct***

Background: This study proposes the investigation of electrical impedance tomography (EIT) as a useful predictor for ventilator weaning.

Methods: The study design was a nested case-control study and patients who were admitted to the intensive care unit and underwent their first tracheal intubation were enrolled. Those who successfully completed ventilator weaning and extubation after the first spontaneous breathing trial (SBT) were included in the weaning success group, while those who did not pass the SBT or received secondary intubation within 48 hours were included in the weaning failure group. In both groups, EIT was adopted to record the monitoring data in three phases: before the SBT (pre-SBT), during the SBT (SBT), and after the SBT (post-SBT).

Results: The study design was a nested case-control study and patients who were admitted to the intensive care unit and underwent their first tracheal intubation were enrolled. Those who successfully completed ventilator weaning and extubation after the first spontaneous breathing trial (SBT) were included in the weaning success group, while those who did not pass the SBT or received secondary intubation within 48 hours were included in the weaning failure group. In both groups, EIT was adopted to record the monitoring data in three phases: before the SBT (pre-SBT), during the SBT (SBT), and after the SBT (post-SBT).

Conclusions: For patients without contraindications to EIT, the application of EIT is recommended to be added to the existing evaluation system for ventilator weaning, as it could help improve the weaning success rate. Further cohort studies are needed to investigate the actual efficacy of EIT after it has been added to the evaluation system.

REV	Shi Y et al.	**The Research Progress of Electrical Impedance Tomography for Lung Monitoring**	*Front Bioeng Biotechnol* ***2021 Oct***

Abstract: Medical imaging can intuitively show people the internal structure, morphological information, and organ functions of the organism, which is one of the most important inspection methods in clinical medical diagnosis. Currently used medical imaging methods can only be applied to some diagnostic occasions after qualitative lesions have been generated, and the general imaging technology is usually accompanied by radiation and other conditions. However, electrical impedance tomography has the advantages of being noninvasive and non-radiative. EIT (Electrical Impedance Tomography) is also widely used in the early diagnosis and treatment of some diseases because of these advantages. At present, EIT is relatively mature and more and more image reconstruction algorithms are used to improve imaging resolution. Hardware technology is also developing rapidly, and the accuracy of data collection and processing is continuously improving. In terms of clinical application, EIT has also been used for pathological treatment of lungs, the brain, and the bladder. In the future, EIT has a good application prospect in the medical field, which can meet the needs of real-time, long-term monitoring and early diagnosis. Aiming at the application of EIT in the treatment of lung pathology, this article reviews the research progress of EIT, image reconstruction algorithms, hardware system design, and clinical applications used in the treatment of lung diseases. Through the research and introduction of several core components of EIT technology, it clarifies the characteristics of EIT system complexity and its solutions, provides research ideas for subsequent research, and once again verifies the broad development prospects of EIT technology in the future.

CLIN	Li Z et al.	**First Attempt at Using Electrical Impedance Tomography to Predict High Flow Nasal Cannula Therapy Outcomes at an Early Phase**	*Front Med* ***2021 Oct***

Objective: Spatial and temporal ventilation distributions in patients with acute respiratory failure during high flow nasal cannula (HFNC) therapy were previously studied with electrical impedance tomography (EIT). The aim of the study was to explore the possibility of predicting HFNC failure based on various EIT-derived parameters.

Methods: High flow nasal cannula failure was defined reintubation within 48 h after HFNC. EIT was performed with the patients spontaneously breathing in the supine position at the start of HFNC. EIT-based indices (comprising the global inhomogeneity index, center of ventilation, ventilation delay, rapid shallow breathing index, minute volume, and inspiration to expiration time) were explored and evaluated at three time points (prior to HFNC, T1; 30 min after HFNC started, T2; and 1 h after, T3).

Results: A total of 46 subjects were included in the final analysis. Eleven subjects had failed HFNC. The time to failure was 27.8 ± 12.4 h. The ROX index (defined as SpO_2/FiO_2/respiratory rate) for HFNC success patients was 8.3 ± 2.7 and for HFNC failure patients, 6.2 ± 1.8 ($p = 0.23$). None of the investigated EIT-based parameters showed significant differences between subjects with HFNC failure and success. Further subgroup analysis indicated that a significant difference in ventilation inhomogeneity was found between ARDS and non-ARDS [0.54 (0.37) vs. 0.46 (0.28) as evaluated with GI, $p < 0.01$]. Ventilation homogeneity significantly improved in ARDS after 60-min HFNC treatment [0.59 (0.20) vs 0.57 (0.19), T1 vs. T3, $p < 0.05$].

Conclusion: Spatial and temporal ventilation distributions were slightly but insignificantly different between the HFNC success and failure groups. HFNC failure could not be predicted by changes in EIT temporal and spatial indexes of ventilation distribution within the first hour. Further studies are required to predict the outcomes of HFNC.

CLIN	**Isasa Reinoso I et al.**	**Long term EIT based compliance monitoring in COVID-19 patients**	*Current Directions in Biomedical Engineering* ***2021 Oct***

Abstract: The COVID-19 is a viral infection that causes respiratory complications. Infected lungs often present ground glass opacities, thus suggesting that medical imaging technologies could provide useful information for the disease diagnosis, treatment, and posterior recovery. The Electrical Impedance Tomography (EIT) is a non-invasive, radiation-free, and continuous technology that generates images by using a sequence of current injections and voltage measurements around the body, making it very appropriate for the study to monitor the regional behaviour of the lung. Moreover, this tool could also be used for a preliminary COVID-19 phenotype classification of the patients. This study is based on the monitoring of lung compliances of two COVID-19-infected patients: the results indicate that one of them could belong to the H-type, while the other is speculated belongs to L-type. It has been concluded that the EIT is a useful tool to obtain information regarding COVID-19 patients and could also be used to classify different phenotypes.

CLIN	**Rauseo M et al.**	**A Pilot Study on Electrical Impedance Tomography During CPAP Trial in Patients With Severe Acute Respiratory Syndrome Coronavirus 2 Pneumonia: The Bright Side of Non-invasive Ventilation**	*Front Physiol* ***2021 Sep***

Background: Different severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pneumonia phenotypes were described that match with different lung compliance and level of oxygenation, thus requiring a personalized ventilator setting. The burden of so many patients and the lack of intensive care unit (ICU) beds often force physicians to choose non-invasive ventilation (NIV) as the first approach, even if no consent has still been reached to discriminate whether it is safer to choose straightforward intubation, paralysis, and protective ventilation. Under such conditions, electrical impedance tomography (EIT), a non-invasive bedside tool to monitor lung ventilation and perfusion defects, could be useful to assess the response of patients to NIV and choose rapidly the right ventilatory strategy.

Objective: The rationale behind this study is that derecruitment is a more efficient measure of positive end expiratory pressure (PEEP)-dependency of patients than recruitment. We hypothesized that patients who derecruit significantly when PEEP is reduced are the ones that do not need early intubation while small end-expiratory lung volume (ΔEELV) variations after a single step of PEEP de-escalation could be predictive of NIV failure.

Materials and Methods: Consecutive patients admitted to ICU with confirmed SARS-CoV-2 pneumonia ventilated in NIV were enrolled. Exclusion criteria were former intubation or NIV lasting > 72 h. A trial of continuos positive airway pressure (CPAP) 12 was applied in every patient for at least 15 min, followed by the second period of CPAP 6, either in the supine or prone position. Besides standard monitoring, ventilation of patients was assessed by EIT, and end-expiratory lung impedance (ΔEELI) (%) was calculated as the difference in EELI between CPAP12 and CPAP6. Tidal volume (Vt), Ve, respiratory rate (RR), and FiO2 were recorded, and ABGs were measured. Data were analyzed offline using the dedicated software. The decision to intubate or continue NIV was in charge of treating physicians, independently from study results. Outcomes of patients in terms of intubation rate and ICU mortality were recorded.

Results: We enrolled 10 male patients, with a mean age of 67 years. Six patients (60%) were successfully treated by NIV until ICU discharge (Group S), and four patients failed NIV and were intubated and switched to MV (Group F). All these patients died in ICU. During the supine CPAP decremental trial, all patients experienced an increase in RR and Ve. ΔEELI was < 40% in Group F and > 50% in Group S. In the prone trial, ΔEELI was > 50% in all patients, while RR decreased in Group S and remained unchanged in Group F.

Conclusion: ΔEELI < 40% after a single PEEP de-escalation step in supine position seems to be a good predictor of poor recruitment and CPAP failure.

REV	Maciejewski D et al.	**Electrical impedance tomography as a tool for monitoring mechanical ventilation. An introduction to the technique**	*Advances in Medical Sciences, Vol 66, Iss 2* ***2021 Sep***

Abstract: Electrical impedance tomography (EIT) is a non-invasive, radiation-free method of diagnostics imaging, allowing for a bedside, real-time dynamic assessment of lung function. It stands as an alternative for other imagining methods, such as computed tomography (CT) or ultrasound. Even though the technique is rather novel, it has a wide variety of possible applications. In the era of modern mechanical ventilation, a dynamic assessment of patient's respiratory condition appears to fulfil the idea of personalized treatment. Additionally, an increasing frequency of respiratory failure among intensive care populations raises demand for improved monitoring tools. This review aims to raise awareness and presents possible implications for the use of EIT in the intensive care setting.

CLIN	Hochhausen N et al.	**Monitoring postoperative lung recovery using electrical impedance tomography in post anesthesia care unit: an observational study**	*J Clin Monit Comput* ***2021 Sep***

Abstract: With electrical impedance tomography (EIT) recruitment and de-recruitment phenomena can be quantified and monitored at bedside. The aim was to examine the feasibility of EIT with respect to monitor atelectasis formation and resolution in the post anesthesia care unit (PACU). In this observational study, 107 postoperative patients were investigated regarding the presence and recovery of atelectasis described by the EIT-derived parameters Global Inhomogeneity Index (GI Index), tidal impedance variation (TIV), and the changes in end-expiratory lung impedance (ΔEELI). We examined whether the presence of obesity (ADP group) has an influence on pulmonary recovery compared to normal weight patients (NWP group). During the stay at PACU, measurements were taken every 15 min. GI Index, TIV, and ΔEELI were calculated for each time point. 107 patients were monitored and EIT-data of 16 patients were excluded for various reasons. EIT-data of 91 patients were analyzed off-line. Their length of stay averaged 80 min (25th and 75th quartile 52–112). The ADP group demonstrated a significantly higher GI Index at PACU arrival ($p < 0.001$). This finding disappeared during their stay at the PACU. Additionally, the ADP group showed a significant increase in ΔEELI between PACU arrival and discharge ($p = 0.025$). Furthermore, TIV showed a significantly lower value during the first 90 min of PACU stay as compared to the time period thereafter ($p = 0.036$). Our findings demonstrate that obesity has an influence on intraoperative atelectasis formation and de-recruitment during PACU stay. The application of EIT in spontaneously breathing PACU patients seems meaningful in monitoring pulmonary recovery.

CR	Foronda, FAK et al.	**Electrical impedance tomography clues to detect pulmonary thrombosis in a teenager with COVID-19**	*Pediatr Radiol* ***2021 Sep***

Abstract: We report a case of pulmonary thrombosis in a teenager during a hypercoagulable state associated with COVID-19 (coronavirus disease 2019) caused by SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2). A condition rare in children and adolescents, pulmonary thrombosis underdiagnosis likely increases morbidity and mortality. A pulmonary thrombosis diagnosis requires a high level of suspicion and relies on the combination of clinical presentation, D-dimer elevation, and computed tomography (CT) pulmonary angiography or ventilation/perfusion scans, imaging techniques that are difficult to perform. Electrical impedance tomography (EIT) has gained attention, as it provides real-time ventilation distribution analysis. In addition, lung pulsatility images can be obtained through this technique using electrocardiogram gating to filter out ventilation. In this case report, the reduced EIT pulsatility corresponded to the perfusion defect found on the CT scan, information that was obtained at the bedside without radiation or contrast exposure.

CLIN	**Eimer C et al.**	**The Effect of Physical Therapy on Regional Lung Function in Critically Ill Patients**	*Front Physiol* **2021 Sep**

Summary: Physiotherapy and the concept of early mobilization has become increasingly important in the ICU. Previous studies have shown a positive effect in terms of shorter hospital stay and improved functional status at discharge. The physiological effect on the lungs has not been investigated so far, therefore, we wanted to explore the effect on lung function during a 15-min physiotherapy session with a 30-min follow-up period.

In our observational, prospective study, we included 20 spontaneously breathing patients with impaired pulmonary gas exchange during their intensive care unit stay after surgery. Using non-invasive functional lung imaging with electrical impedance tomography (EIT), we examined regional lung function of the patients before, during, and after a physiotherapy session. EIT allowed continuous assessment of the distribution of ventilation in the lungs.

We observed that ventilation of the posterior lung segments increased significantly during physiotherapy, when patients assumed a sitting and partially standing position. After the patients returned to the initial lying position before physiotherapy, the observed effect subsided immediately. Nevertheless, the follow-up showed a slow increase in end-expiratory lung volume.

CLIN	**Christanto A, Darinafitri I**	**The Role of Electrical Impedance Tomography in Lung Imaging**	*CDK Journal* **2021 Sep**

Abstract: Lung imaging in certain conditions, such as in patients with Acute Respiratory Distress Syndrome (ARDS), poses its challenges. Heterogeneity of lung damage in ARDS can only be detected by CT scan, causing treatment delay and increased mortality. Difficulty to perform standard imaging such as CXR in such patients also contributes to the increasing incidence of VALI (Ventilator-Associated Lung Injury) due to diagnosis delay. EIT (Electrical Impedance Tomography) is a novel imaging method that uses electrical impedance modality. EIT is a bedside, continuous imaging method which can depict both solids and fluids (including air) in body cavities, both statically and dynamically. EIT carries the potency to be the primary lung imaging method for patients in intensive care in the future.

CLIN/EDIT	**Quing P et al.**	**Electrical impedance tomography captures heterogeneous lung ventilation that may be associated with ineffective inspiratory efforts**	*Crit Care* **2021 Aug**

Introduction: Patient-ventilator asynchrony (PVA) is common in patients receiving mechanical ventilation, which is due to mismatch between neural and mechanical inspiratory time. This occurs primarily when the triggering and cycling-off of ventilatory assistance are not synchronized with the patient's inspiratory efforts. Ineffective inspiratory effort during expiration (IEE) is one of the most frequent type of PVA [1], which is associated with worse clinical outcomes [2]. Despite the extensive investigations on its mechanisms and recognition, rare notice was put on the regional ventilation distribution during IEE or other types of PVA. Electrical impedance tomography (EIT) emerges as an effective tool to monitor the regional lung ventilation [3]. In this study, we aim to describe an EIT-based method to assess heterogeneous lung ventilation, which may be associated with IEE.

In conclusion, EIT is able to characterize the imbalanced ventilation that may be associated with IEE. It has the potential to discover IEE cycles without corresponding characteristics in the ventilator waveform. The findings require further validations with more subjects to confirm whether these cycles reflect asynchronous breath using esophageal pressure or electrical diaphragm activity, and if they will compromise the ventilatory support for the patients.

CLIN	Jung K et al.	**Comparison of Positive End-Expiratory Pressure versus Tidal Volume-Induced Ventilator-Driven Alveolar Recruitment Maneuver in Robotic Prostatectomy: A Randomized Controlled Study**	*J. Clin. Med.* ***2021 Aug***

Abstract: We evaluated the pulmonary effects of two ventilator-driven alveolar recruitment maneuver (ARM) methods during laparoscopic surgery. Methods: Sixty-four patients undergoing robotic prostatectomy were randomized into two groups: incrementally increasing positive end-expiratory pressure in a stepwise manner (PEEP group) versus tidal volume (VT group). We performed each ARM after induction of anesthesia in the supine position (T1), after pneumoperitoneum in the Trendelenburg position (T2), and after peritoneum desufflation in the supine position (T3). The primary outcome was change in end-expiratory lung impedance (EELI) before and 5 min after ARM at T3, measured by electrical impedance tomography. Results: The PEEP group showed significantly higher increasing EELI 5 min after ARM than the VT group at T1 and T3 (median [IQR] 460 [180,800] vs. 200 [80,315], p = 0.002 and 280 [170,420] vs. 95 [55,175], p = 0.004, respectively; PEEP group vs. VT group). The PEEP group showed significantly higher lung compliance and lower driving pressure at T1 and T3. However, there was no significant difference in EELI change, lung compliance, or driving pressure after ARM at T2. Conclusions: The ventilator-driven ARM by the increasing PEEP method led to greater improvements in lung compliance at the end of laparoscopic surgery than the increasing VT method.

CLIN	He H et al.	**Three broad classifications of acute respiratory failure etiologies based on regional ventilation and perfusion by electrical impedance tomography: a hypothesis-generating study**	*Ann. Intensive Care* ***2021 Aug***

Background: The aim of this study was to validate whether regional ventilation and perfusion data measured by electrical impedance tomography (EIT) with saline bolus could discriminate three broad acute respiratory failure (ARF) etiologies.

Methods: Perfusion image was generated from EIT-based impedance–time curves caused by 10 ml 10% NaCl injection during a respiratory hold. Ventilation image was captured before the breath holding period under regular mechanical ventilation. $DeadSpace_{\%}$, $Shunt_{\%}$ and $VQMatch_{\%}$ were calculated based on lung perfusion and ventilation images. Ventilation and perfusion maps were divided into four cross-quadrants (lower left and right, upper left and right). Regional distribution defects of each quadrant were scored as 0 (distribution% ≥ 15%), 1 (15% > distribution% ≥ 10%) and 2 (distribution% < 10%). Data percentile distributions in the control group and clinical simplicity were taken into consideration when defining the scores. Overall defect scores ($Defect_V$, $Defect_Q$ and $Defect_{V+Q}$) were the sum of four cross-quadrants of the corresponding images.

Results: A total of 108 ICU patients were prospectively included: 93 with ARF and 15 without as a control. PaO_2/FiO_2 was significantly correlated with $VQMatch_{\%}$ (r = 0.324, P = 0.001). Three broad etiologies of ARF were identified based on clinical judgment: pulmonary embolism-related disease (PED, n = 14); diffuse lung involvement disease (DLD, n = 21) and focal lung involvement disease (FLD, n = 58). The PED group had a significantly higher $DeadSpace_{\%}$ [40(24)% vs. 14(15)%, PED group vs. the rest of the subjects; median(interquartile range); P < 0.0001] and $Defect_Q$ score than the other groups [1(1) vs. 0(1), PED vs. the rest; P < 0.0001]. The DLD group had a significantly lower $Defect_{V+Q}$ score than the PED and FLD groups [0(1) vs. 2.5(2) vs. 3(3), DLD vs. PED vs. FLD; P < 0.0001]. The FLD group had a significantly higher $Defect_V$ score than the other groups [2(2) vs. 0(1), FLD vs. the rest; P < 0.0001]. The area under the receiver operating characteristic (AUC) for using $DeadSpace_{\%}$ to identify PED was 0.894 in all ARF patients. The AUC for using the $Defect_{V+Q}$ score to identify DLD was 0.893. The AUC for using the $Defect_V$ score to identify FLD was 0.832.

Conclusions: Our study showed that it was feasible to characterize three broad etiologies of ARF with EIT-based regional ventilation and perfusion. Further study is required to validate clinical applicability of this method.

CR	**Brunin Y et al.**	**Lung Recruiting Effect of Prone Positioning in Spontaneously Breathing Patients with COVID-19 Assessed by Electrical Impedance Tomography**	*Am J Respir Crit Care Med* **2021 Aug**

Introduction: A 72-year-old male known for obesity (body mass index of 38 kg.m-2) and smoking was admitted to intensive care unit (ICU) for acute respiratory failure. Chest CT-scan revealed interstitial lung infiltrates with sub pleural and posterior lung condensation (Figure 1). Coronavirus disease-19 (COVID-19) pneumonia was confirmed by a positive result of real-time reverse transcriptase-polymerase chain reaction from nasal and pharyngeal swab ...

ES	**Scaramuzzo G et al.**	**Calculation of Transpulmonary Pressure From Regional Ventilation Displayed by Electrical Impedance Tomography in Acute Respiratory Distress Syndrome**	*Front. Physiol* **2021 Jul**

Abstract: Transpulmonary driving pressure (DP_L) corresponds to the cyclical stress imposed on the lung parenchyma during tidal breathing and, therefore, can be used to assess the risk of ventilator-induced lung injury (VILI). Its measurement at the bedside requires the use of esophageal pressure (Peso), which is sometimes technically challenging. Recently, it has been demonstrated how in an animal model of ARDS, the transpulmonary pressure (P_L) measured with Peso calculated with the absolute values method (P_L = Paw—Peso) is equivalent to the transpulmonary pressure directly measured using pleural sensors in the central-dependent part of the lung. We hypothesized that, since the PL derived from Peso reflects the regional behavior of the lung, it could exist a relationship between regional parameters measured by electrical impedance tomography (EIT) and driving P_L (DP_L). Moreover, we explored if, by integrating airways pressure data and EIT data, it could be possible to estimate non-invasively DP_L and consequently lung elastance (EL) and elastance-derived inspiratory P_L (PI). We analyzed 59 measurements from 20 patients with ARDS. There was a significant intra-patient correlation between EIT derived regional compliance in regions of interest (ROI1) ($r = 0.5$, $p = 0.001$), ROI2 ($r = -0.68$, $p < 0.001$), and ROI3 ($r = -0.4$, $p = 0.002$), and DP_L. A multiple linear regression successfully predicted DPL based on respiratory system elastance (Ers), ideal body weight (IBW), roi1%, roi2%, and roi3% ($R^2 = 0.84$, $p < 0.001$). The corresponding Bland-Altmann analysis showed a bias of −1.4e-007 cmH2O and limits of agreement (LoA) of −2.4–2.4 cmH_2O. EL and PI calculated using EIT showed good agreement ($R^2 = 0.89$, $p < 0.001$ and $R^2 = 0.75$, $p < 0.001$) with the esophageal derived correspondent variables. In conclusion, DP_L has a good correlation with EIT-derived parameters in the central lung. DP_L, PI, and EL can be estimated with good accuracy non-invasively combining information coming from EIT and airway pressure.

REV	**Sella N et al.**	**Electrical impedance tomography: A compass for the safe route to optimal PEEP**	*Respiratory Medicine* **2021 Jul**

Abstract: Setting the proper level of positive end-expiratory pressure (PEEP) is a cornerstone of lung protective ventilation. PEEP keeps the alveoli open at the end of expiration, thus reducing atelectrauma and shunt. However, excessive PEEP may contribute to alveolar overdistension. Electrical impedance tomography (EIT) is a non-invasive bedside tool that monitors in real-time ventilation distribution. Aim of this narrative review is summarizing the techniques for EIT-guided PEEP titration, while providing useful insights to enhance comprehension on advantages and limits of EIT for current and future users. EIT detects thoracic impedance to alternating electrical currents between pairs of electrodes and, through the analysis of its temporal and spatial variation, reconstructs a two-dimensional slice image of the lung depicting regional variation of ventilation and perfusion. Several EIT-based methods have been proposed for PEEP titration. The first described technique estimates the variations of regional lung compliance during a decremental PEEP trial, after lung recruitment. The optimal PEEP value is represented by the best compromise between lung collapse and overdistension. Later on, a second technique assessing alveolar recruitment by variation of the end-expiratory lung impedance was validated. Finally, the global inhomogeneity index and the regional ventilation delay, two EIT-derived parameters, showed promising results selecting the optimal PEEP value as the one that presents the lowest global inhomogeneity index or the lowest regional ventilation delay. In conclusion EIT represents a promising technique to individualize PEEP in mechanically ventilated patients. Whether EIT is the best technique for this purpose and the overall influence of personalizing PEEP on clinical outcome remains to be determined.

CR	Vieira de Campos C et al.	**Electrical Impedance Tomography: Monitoring of Pulmonary Ventilation in Pediatric Cardiac Postoperative**	*J Cardio Case Rep* ***2021 Jun***

Introduction: The electrical impedance tomography (EIT) is a bedside monitoring tool that noninvasively visualizes local ventilation and arguably lung perfusion distribution. Is a non-invasive radiation-free monitoring technique that provides images based on tissue electrical conductivity of the chest [1]. Some studies [2,3] including adult patients have applied EIT in the context of the preoperative, intraoperative period, extending to the postoperative follow-up of several clinical situations. However, so far there are no scientific publications in this context in the pediatric age group.

Case: We present the case of an 8-month-old girl with unbalanced atrioventricular septal defect, small right-ventricle and non-restrictive atrial and ventricular septal defects, status-post pulmonary artery (PA) banding at 3 months, who underwent a Superior Bilateral Vena Cava anastomosis, atrioventricular valve plasty and PA re-banding (total closure was not possible due to hypoxia). ...

CLIN	Soulé C et al.	**Assessment of Electrical Impedance Tomography to Set Optimal Positive End-Expiratory Pressure for Venoarterial Extracorporeal Membrane Oxygenation-Treated Patients**	*Crit Care Med* ***2021 Jun***

Objectives: Patients on venoarterial extracorporeal membrane oxygenation have many risk factors for pulmonary complications in addition to their heart failure. Optimal positive end-expiratory pressure is unknown in these patients. The aim was to evaluate the ability of electrical impedance tomography to help the physician to select the optimal positive end-expiratory pressure in venoarterial extracorporeal membrane oxygenation treated and mechanically ventilated patients during a positive end-expiratory pressure trial.

Design: Observational prospective monocentric.
Setting: University hospital.
Patients: Patients (n = 23) older than 18 years old, on mechanical ventilation and venoarterial extracorporeal membrane oxygenation.

Interventions: A decreasing positive end-expiratory pressure trial (20-5 cm H2O) in increments of 5 cm H2O was performed and monitored by a collection of clinical parameters, ventilatory and ultrasonographic (cardiac and pulmonary) to define an optimal positive end-expiratory pressure according to respiratory criteria (optimal positive end-expiratory pressure selected by physician with respiratory parameters), and then adjusted according to hemodynamic and cardiac tolerances (optimal positive end-expiratory pressure selected by physician with respiratory, hemodynamic, and echocardiographic parameters). At the same time, electrical impedance tomography data (regional distribution of ventilation, compliance, and overdistension collapse) were recorded and analyzed retrospectively to define the optimal positive end-expiratory pressure.

Measurements and main results: The median of this optimal positive end-expiratory pressure was 10 cm H2O in our population. Electrical impedance tomography showed that increasing positive end-expiratory pressure promoted overdistention of ventral lung, maximum at positive end-expiratory pressure 20 cm H20 (34% [interquartile range, 24.5-40]). Decreasing positive end-expiratory pressure resulted in collapse of dorsal lung (29% [interquartile range, 21-45.8]). The optimal positive end-expiratory pressure selected by physician with respiratory parameters was not different from the positive end-expiratory pressure chosen by the electrical impedance tomography. However, there is a negative impact of a high level of intrathoracic pressure on hemodynamic and cardiac tolerances.

Conclusions: Our results support that electrical impedance tomography appears predictive to define optimal positive end-expiratory pressure on venoarterial extracorporeal membrane oxygenation, aided by echocardiography to optimize hemodynamic assessment and management.

CR	Simon P et al.	**Individualized versus Fixed Positive End-expiratory Pressure for Intraoperative Mechanical Ventilation in Obese Patients: A Secondary Analysis**	*Anesthesiology* **2021 Jun**

Background: General anesthesia may cause atelectasis and deterioration in oxygenation in obese patients. The authors hypothesized that individualized positive end-expiratory pressure (PEEP) improves intraoperative oxygenation and ventilation distribution compared to fixed PEEP.

Methods: This secondary analysis included all obese patients recruited at University Hospital of Leipzig from the multicenter Protective Intraoperative Ventilation with Higher versus Lower Levels of Positive End-Expiratory Pressure in Obese Patients (PROBESE) trial (n = 42) and likewise all obese patients from a local single-center trial (n = 54). Inclusion criteria for both trials were elective laparoscopic abdominal surgery, body mass index greater than or equal to 35 kg/m^2, and Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) score greater than or equal to 26. Patients were randomized to PEEP of 4 cm H_2O (n = 19) or a recruitment maneuver followed by PEEP of 12 cm H_2O (n = 21) in the PROBESE study. In the single-center study, they were randomized to PEEP of 5 cm H_2O (n = 25) or a recruitment maneuver followed by individualized PEEP (n = 25) determined by electrical impedance tomography. Primary endpoint was Pao_2/inspiratory oxygen fraction before extubation and secondary endpoints included intraoperative tidal volume distribution to dependent lung and driving pressure.

Results: Ninety patients were evaluated in three groups after combining the two lower PEEP groups. Median individualized PEEP was 18 (interquartile range, 16 to 22; range, 10 to 26) cm H2O. Pao2/inspiratory oxygen fraction before extubation was 515 (individual PEEP), 370 (fixed PEEP of 12 cm H_2O), and 305 (fixed PEEP of 4 to 5 cm H2O) mmHg (difference to individualized PEEP, 145; 95% CI, 91 to 200; $P < 0.001$ for fixed PEEP of 12 cm H_2O and 210; 95% CI, 164 to 257; $P < 0.001$ for fixed PEEP of 4 to 5 cm H_2O). Intraoperative tidal volume in the dependent lung areas was 43.9% (individualized PEEP), 25.9% (fixed PEEP of 12 cm H_2O) and 26.8% (fixed PEEP of 4 to 5 cm H_2O) (difference to individualized PEEP: 18.0%; 95% CI, 8.0 to 20.7; $P < 0.001$ for fixed PEEP of 12 cm H_2O and 17.1%; 95% CI, 10.0 to 20.6; $P < 0.001$ for fixed PEEP of 4 to 5 cm H_2O). Mean intraoperative driving pressure was 9.8 cm H_2O (individualized PEEP), 14.4 cm H_2O (fixed PEEP of 12 cm H_2O), and 18.8 cm H_2O (fixed PEEP of 4 to 5 cm H_2O), $P < 0.001$.

Conclusions: This secondary analysis of obese patients undergoing laparoscopic surgery found better oxygenation, lower driving pressures, and redistribution of ventilation toward dependent lung areas measured by electrical impedance tomography using individualized PEEP. The impact on patient outcome remains unclear....

CLIN	**He H et al.**	**Early individualized positive end-expiratory pressure guided by electrical impedance tomography in acute respiratory distress syndrome: a randomized controlled clinical trial**	*Crit Care* **2021 Jun**

Background: Individualized positive end-expiratory pressure (PEEP) by electrical impedance tomography (EIT) has potential interest in the optimization of ventilation distribution in acute respiratory distress syndrome (ARDS). The aim of the study was to determine whether early individualized titration of PEEP with EIT improved outcomes in patients with ARDS.

Methods: A total of 117 ARDS patients receiving mechanical ventilation were randomly assigned to EIT group (n = 61, PEEP adjusted based on ventilation distribution) or control group (n = 56, low PEEP/FiO2 table). The primary outcome was 28-day mortality. Secondary and exploratory outcomes were ventilator-free days, length of ICU stay, incidence of pneumothorax and barotrauma, and difference in Sequential Organ Failure Assessment (SOFA) score at day 1 (ΔD1-SOFA) and day 2 (ΔD2-SOFA) compared with baseline.

Measurements and main results: There was no statistical difference in the value of PEEP between the EIT group and control group, but the combination of PEEP and FiO2 was different between groups. In the control group, a significantly positive correlation was found between the PEEP value and the corresponding FiO2 ($r = 0.47$, $p < 0.00001$) since a given matched table was used for PEEP settings. Diverse combinations of PEEP and FiO2 were found in the EIT group ($r = 0.05$, $p = 0.68$). There was no significant difference in mortality rate (21% vs. 27%, EIT vs. control, $p = 0.63$), ICU length of stay (13.0 (7.0, 25.0) vs 10.0 (7.0, 14.8), median (25th–75th percentile); $p = 0.17$), and ventilator-free days at day 28 (14.0 (2.0, 23.0) vs 19.0 (0.0, 24.0), $p = 0.55$) between the two groups. The incidence of new barotrauma was zero. Compared with control group, significantly lower ΔD1-SOFA and ΔD2-SOFA were found in the EIT group ($p < 0.001$) in a post hoc comparison. Moreover, the EIT group exhibited a significant decrease of SOFA at day 2 compared with baseline (paired t-test, difference by − 1 (− 3.5, 0), $p = 0.001$). However, the control group did show a similar decrease (difference by 1 (− 2, 2), $p = 0.131$).

Conclusion: Our study showed a 6% absolute decrease in mortality in the EIT group: a statistically non-significant, but clinically non-negligible result. This result along with the showed improvement in organ function might justify further research to validate the beneficial effect of individualized EIT-guided PEEP setting on clinical outcomes of patients with ARDS.

ES	**Chen Z et al.**	**Potential effect of pulmonary fluid viscosity on positive end-expiratory pressure and regional distribution of lung ventilation in acute respiratory distress syndrome**	*Clinical Biomechanics* **2021 Jun**

Background: Computational fluid dynamic simulations have showed that the elevated viscosity of pulmonary fluids may increase the likelihood of airway closure, thus exacerbating inhomogeneity of regional lung ventilation. Unfortunately, there have been few studies directed toward measurements of viscosity of pulmonary fluids and its effect on airway opening pressure and regional distribution of lung ventilation in acute respiratory distress syndrome.

Methods: In this study, pulmonary fluids from 8 ARDS patients were measured using a cone and plate rheometer on days 1, 3, 7 and 14 in the treatment of the disorder. Ventilator settings were simultaneously recorded, including tidal volume, positive end-expiratory pressure, fraction of inspired oxygen (FiO_2), and so on. The regional distribution of lung ventilation was monitored by a bedside electrical impedance tomography system.

Findings: The results showed that rheological properties of pulmonary fluids behaved as either Newtonian or non-Newtonian across all patients studied. Significant intersubject and intrasubject variations in measured viscosities were observed, spanning ranges from approximately 1 cP to 7×10^4 cP at shear rates between 0.075–750 s^{-1}. The product of the positive end-expiratory airway pressure and fraction of inspired oxygen was well correlated with fluid viscosity in patients with high viscosity pulmonary fluids. Furthermore, lung ventilation in these patients was highly inhomogeneous and influenced by rheology of pulmonary fluids.

Interpretation: The current findings provided the direct clinical data for theoretical models of airway reopening and may have important clinical implications in explaining inhomogeneity of lung ventilation and selecting initial levels of positive end-expiratory pressure in mechanically ventilated patients.

CLIN	Yang L et al.	**Regional ventilation distribution in healthy lungs: can reference values be established for electrical impedance tomography parameters?**	*Ann Transl Med* **2021 May**

Objectives: Although electrical impedance tomography (EIT) is widely used for monitoring regional ventilation distribution, reference values have yet to be established for clinical use. The present study aimed to evaluate the feasibility of creating reference values for standard EIT parameters for potential clinical application.

Methods: A total of 75 participants with healthy lungs were included in this prospective study (male:female, 48:27; age, 34±14 years; height, 172±7 cm; weight, 73±12 kg). The subjects were examined during spontaneous breathing in the supine position. EIT measurements were performed at the level of the 4th intercostal space. Commonly used EIT-based parameters, including the center of ventilation (CoV), dorsal and most dorsal fractions of ventilation distribution (TVD and TVROI4 respectively), global inhomogeneity (GI) index, and standard deviation of regional ventilation delay index (RVDSD) were calculated.

Results: Following outlier detection, EIT data from 71 subjects were finally evaluated. The values of the evaluated parameters were: CoV, 48.7%±1.7%; TVD, 48.1%±5.4%; TVROI4, 7.1%±1.8%; GI, 0.49±0.04; and RVDSD, 7.0±2.0. The coefficients of variation for CoV and GI were low (0.03 and 0.07, respectively), but those for TVROI4 and RVD_{SD} were comparatively high (0.26 and 0.28, respectively). None of the evaluated parameters showed a significant correlation with age. The GI index showed a weak but significant correlation with body mass index (R=0.29, P=0.01). The RVD_{SD} was slightly higher in males than in females.

Conclusions: Our study indicated that CoV and GI were stable parameters with small coefficients of variation in participants with healthy lungs. The creation of EIT parameter reference values for setting treatment targets may be feasible.

CR	Taenaka H et al.	**Individualized ventilatory management in patients with COVID-19-associated acute respiratory distress syndrome**	*Respiratory Medicine* **2021 May**

Abstract: Due to the coronavirus disease 2019 pandemic, the number of coronavirus disease 2019-associated acute respiratory distress syndrome is rapidly increasing. The heterogeneity of coronavirus disease 2019-associated acute respiratory distress syndrome contributes to the complexity of managing patients. Here we described two patients with coronavirus disease 2019-associated acute respiratory distress syndrome showing that the bedside physiological approach including careful evaluation of respiratory system mechanics and visualization of ventilation with electrical impedance tomography was useful to individualize ventilatory management.

REV	Wu Y et al.	**Electrical Impedance Tomography for Biomedical Applications: Circuits and Systems Review**	*IEEE Open J. Circ. Syst.* **2021 Apr**

Abstract: There has been considerable interest in electrical impedance tomography (EIT) to provide low-cost, radiation-free, real-time and wearable means for physiological status monitoring. To be competitive with other well-established imaging modalities, it is important to understand the requirements of the specific application and determine a suitable system design. This paper presents an overview of EIT circuits and systems including architectures, current drivers, analog front-end and demodulation circuits, with emphasis on integrated circuit implementations. Commonly used circuit topologies are detailed, and tradeoffs are discussed to aid in choosing an appropriate design based on the application and system priorities. The paper also describes a number of integrated EIT systems for biomedical applications, as well as discussing current challenges and possible future directions.

CLIN	**Longhini F et al.**	**High-flow nasal cannula oxygen therapy for outpatients undergoing flexible bronchoscopy: a randomised controlled tri**	*Thorax* **2021 Apr**

Introduction: High-flow nasal cannula (HFNC) provides benefits to patients undergoing flexible bronchoscopy (FOB). We compared the effects of HFNC versus standard therapy (ST) on gas exchange, lung volume and diaphragm function in patients undergoing FOB for bronchoalveolar lavage (BAL).

Methods: 36 outpatients were randomised to ST or HFNC. Arterial blood gases, episodes of severe desaturation, changes of end-expiratory lung impedance (ΔEELI), diaphragm ultrasound were recorded. Measurements were done at baseline (T0), after bronchoscope insertion (T1), at the end of the procedure (T2) and 10 min afterwards (T3).

Results: Arterial partial oxygen pressure (PaO_2) was not different between T0 (10.8 (95% CI 8.7 to 12.0) kPa and T2 (11.1 (95% CI 10.4 to 12.0) kPa) with HFNC, while decreased from 11.1 (95% CI 10.5 to 12.1) to 9.1 (95% CI 8.4 to 9.8) kPa with ST. At T2, PaO_2 was significantly higher with HFNC than with ST ($p<0.001$). Also, with HFNC, compared with ST, fewer desaturations occurred (11% vs 56%; $p<0.01$). ΔEELI was no different at the different time points with HFNC, while with ST there was a significant decrease at T1 (−170 (95% CI −382 to −32) mL, p=0.003), T2 (−211 (95% CI −425 to −148) mL, p<0.001) and T3 (−213 (95% CI −398 to −81) mL, p<0.001), as opposed to T0. EELI was lower with ST than HFNC at T1 (p=0.006), T2 (p=0.001) and T3 (p=0.002). Diaphragm displacement was no different between groups (p=0.748), while the thickening fraction significantly increased at T1 and T2 with ST only (p<0.01).

Conclusions: During FOB for BAL, HFNC improves gas exchange, avoiding loss of end-expiratory lung volume and preventing increase of diaphragm activation.

REV	**Kotani T, Shono A**	**Roles of Electrical Impedance Tomography in Determining a Lung Protective Strategy for Acute Respiratory Distress Syndrome in the Era of Coronavirus Disease 2019**	*JMA J* **2021 Apr**

Abstract: Electrical impedance tomography (EIT) is noninvasive and can be used at the bedside for real-time evaluation to identify ventilation distribution of infected lungs. This review briefly describes the basic principle of EIT and summarizes the latest findings on its potential contribution to lung protective strategies in coronavirus disease 2019 patients. Additionally, experimental approaches for detecting the distribution of pulmonary blood flow in coronavirus disease 2019 patients are presented. The findings underscore the role of EIT in determining lung protective strategies for coronavirus disease 2019-associated acute respiratory distress syndrome.

CR	**Rozé H et al.**	**Electrical Impedance Tomography to Detect Airway Closure Heterogeneity in Asymmetrical Acute Respiratory Distress Syndrome**	*Am J Respir Crit Care Med* **2021 Febr**

To the Editor: Because of airway closure, tidal inflation starts only when an airway opening pressure (AOP) has been overcome in at least one-third of patients with acute respiratory distress syndrome (ARDS) (1, 2). Airway closure participates in the heterogeneity of tidal ventilation distribution and can possibly amplify ventilator-induced lung injury (3). The detection of airway closure and the measurement of a global (or minimal) AOP require performing a low-flow pressure–volume (PV) or pressure–time curve. However, lung injury and hence tidal ventilation can be heterogeneous between the two lungs. In a center where we frequently treat surgical patients with asymmetrical ARDS (e.g., after thoracic surgery), we wondered about the behavior of each lung in such situations. We tested the hypothesis that an electrical impedance tomography (EIT)-derived regional PV curve could assess the AOP of each lung. We used EIT to assess and measure the regional AOP of each lung in asymmetrical ARDS based on the airway pressure at which regional impedance increased in each lung. We also partitioned each lung in three regions along a vertical axis. We then compared these AOPs with the level of positive end-expiratory pressure (PEEP) proposed by the global compromise between alveolar collapse and overdistension on EIT (4).

CLIN	Martinsson A et al.	Lung recruitment in the prone position after cardiac surgery: a randomised controlled study	*Brit J An* ***2021 Febr***

Introduction: Atelectasis after cardiac surgery is common and promotes ventilation/perfusion mismatch, infection, and delayed discharge from critical care. Recruitment manoeuvres are often performed to reduce atelectasis. In severe respiratory failure, recruitment manoeuvres in the prone position may increase oxygenation, survival, or both. We compared the effects of recruitment manoeuvres in the prone vs supine position on lung aeration and oxygenation in cardiac surgical patients.

Methods: Subjects were randomised to recruitment manoeuvres (40 cm H_2O peak inspiratory pressure and 20 cm H_2O PEEP for 30 s) in either the prone or supine position after uncomplicated cardiac surgery. The co-primary endpoints were lung aeration (end-expiratory lung volume measured by electrical impedance tomography (arbitrary units [a.u.]) and lung oxygenation (ratio of arterial oxygen partial pressure to fractional inspired oxygen [Pao_2/FiO_2 ratio]). Secondary outcomes included postoperative oxygen requirement and adverse events.

Results: Thirty subjects (27% female; age, 48–81 yr) were recruited. Dorsal lung tidal volume was higher after prone recruitment manoeuvres (363 a.u.; 95% confidence intervals [CI], 283–443; n=15) after extubation, compared with supine recruitment manoeuvres (212 a.u.; 95% CI, 170–254; n=15; P<0.001). Prone recruitment manoeuvres increased dorsal end-expiratory lung volume by 724 a.u. (95% CI, 456–992) after extubation, compared with 163 a.u. decrease (95% CI, 73–252) after supine recruitment manoeuvres (P<0.001). The Pao2/FiO2 ratio after extubation was higher after prone recruitment manoeuvres (46.6; 95% CI, 40.7–53.0) compared with supine recruitment manoeuvres (39.3; 95% CI, 34.8–43.8; P=0.04). Oxygen therapy after extubation was shorter after prone (33 h [13]) vs supine recruitment manoeuvres (52 h [22]; P=0.01). No adverse events occurred.

Conclusions: Recruitment manoeuvres in the prone position after cardiac surgery improve lung aeration and oxygenation.

CLIN	Lazarow L et al.	Regional lung function measures determined by electrical impedance tomography during repetitive ventilation manoeuvres in patients with COPD	*Physiol Meas* ***2021 Feb***

Objective: Current standards for conducting spirometry examinations recommend that the ventilation manoeuvres needed in pulmonary function testing are carried out repeatedly during sessions. Chest electrical impedance tomography (EIT) can determine the presence of ventilation heterogeneity during such manoeuvres, which increases the information content derived from such examinations. The aim of this study was to characterise regional lung function in patients with chronic obstructive pulmonary disease (COPD) during repetitive forced full ventilation manoeuvres. Regional lung function measures derived from these manoeuvres were compared with quiet tidal breathing.

Approach: Sixty hospitalised patients were examined during up to three repeated ventilation manoeuvres. Acceptable spirometry manoeuvres were performed and EIT recordings suitable for analysis obtained in 53 patients (12 women, 41 men; age: 68 ± 12 years (mean ± SD)). Pixel values of tidal volume, forced full inspiratory and expiratory volume in 1 s, and forced inspiratory and expiratory vital capacity were calculated from the EIT data. Spatial ventilation heterogeneity was assessed using the coefficient of variation, global inhomogeneity index, and centres and regional fractions of ventilation. Temporal inhomogeneity was determined by examining the pixel expiration times needed to exhale 50% and 75% of regional forced vital capacity.

Main results: All EIT-derived measures of regional lung function showed reproducible results during repetitive examinations. Parameters of spatial heterogeneity obtained from quiet tidal breathing were comparable with the measures derived from the forced manoeuvres.

Significance: Measures of spatial and temporal ventilation heterogeneity obtained in COPD patients by EIT provide comparable findings during repeated examinations within one testing session. Quiet tidal breathing generates similar information on ventilation heterogeneity as forced manoeuvres that demand a high amount of patient effort.

CLIN	Hsu HJ et al.	**Positive end-expiratory pressure titration with electrical impedance tomography and pressure–volume curve: a randomized trial in moderate to severe ARDS**	*Physiol Meas* **2021 Feb**

Objective: The aim of the study was to compare titration of positive end-expiratory pressure (PEEP) with electrical impedance tomography (EIT) and with ventilator-embedded pressure–volume (PV) loop in moderate to severe acute respiratory distress syndrome (ARDS).

Approach: Eighty-seven moderate to severe ARDS patients (arterial oxygen partial pressure to fractional inspired oxygen ratio, $PaO_2/FiO_2 \leq 200$ mmHg) were randomized to either EIT group (n = 42) or PV group (n = 45). All patients received identical medical care using the same general support guidelines and protective mechanical ventilation. In the EIT group, the selected PEEP equaled the airway pressure at the intercept between cumulated collapse and overdistension percentages curves and in the PV group, at the pressure where maximal hysteresis was reached.

Main results: Baseline characteristics and settings were comparable between the groups. After optimization, PEEP was significantly higher in the PV group (17.4 ± 1.7 versus 16.2 ± 2.6 cmH_2O, PV versus EIT groups, p = 0.02). After 48 h, driving pressure was significantly higher in the PV group (12.4 ± 3.6 versus 10.9 ± 2.5 cmH_2O, p = 0.04). Lung mechanics and oxygenation were better in the EIT group but did not statistically differ between the groups. The survival rate was lower in the PV group (44.4% versus 69.0%, p = 0.02; hazard ratio 2.1, confidence interval 1·1–3.9). None of the other pre-specified exploratory clinical endpoints were significantly different.

Significance: In moderate to severe ARDS, PEEP titration guided with EIT, compared with PV curve, might be associated with improved driving pressure and survival rate.

CLIN	Cornejo R et al.	**Estimation of changes in cyclic lung strain by electrical impedance tomography: Proof-of-concept study**	*Acta Anaesthesiol Scand* **2021 Feb**

Rationale: Cyclic strain may be a determinant of ventilator-induced lung injury. The standard for strain assessment is the computed tomography (CT), which does not allow continuous monitoring and exposes to radiation. Electrical impedance tomography (EIT) is able to monitor changes in regional lung ventilation. In addition, there is a correlation between mechanical deformation of materials and detectable changes in its electrical impedance, making EIT a potential surrogate for cyclic lung strain measured by CT (StrainCT).

Objectives: To compare the global StrainCT with the change in electrical impedance (ΔZ).

Methods: Acute respiratory distress syndrome patients under mechanical ventilation (VT 6 mL/kg ideal body weight with positive end-expiratory pressure 5 [PEEP 5] and best PEEP according to EIT) underwent whole-lung CT at end-inspiration and end-expiration. Biomechanical analysis was used to construct 3D maps and determine StrainCT at different levels of PEEP. CT and EIT acquisitions were performed simultaneously. Multilevel analysis was employed to determine the causal association between StrainCT and ΔZ. Linear regression models were used to predict the change in lung $Strain_{CT}$ between different PEEP levels based on the change in ΔZ.

Main results: $Strain_{CT}$ was positively and independently associated with ΔZ at global level (P < .01). Furthermore, the change in $Strain_{CT}$ (between PEEP 5 and Best PEEP) was accurately predicted by the change in ΔZ (R^2 0.855, P < .001 at global level) with a high agreement between predicted and measured $Strain_{CT}$.

Conclusions: The change in electrical impedance may provide a noninvasive assessment of global cyclic strain, without radiation at bedside.

CR	Zhao Z et al.	**The use of electrical impedance tomography for individualized ventilation strategy in COVID-19: a case report**	*BMC Pulm Med* **2021 Jan**

Background: Clinical management of COVID-19 requires close monitoring of lung function. While computed tomography (CT) offers ideal way to identify the phenotypes, it cannot monitor the patient response to therapeutic interventions. We present a case of ventilation management for a COVID-19 patient where electrical impedance tomography (EIT) was used to personalize care.

Case presentation: The patient developed acute respiratory distress syndrome, required invasive mechanical ventilation, and was subsequently weaned. EIT was used multiple times: to titrate the positive end-expiratory pressure, understand the influence of body position, and guide the support levels during weaning and after extubation. We show how EIT provides bedside monitoring of the patient´s response to various therapeutic interventions and helps guide treatments.

Conclusion: EIT provides unique information that may help the ventilation management in the pandemic of COVID-19.

CR	Shono A, Kotani T, Frerichs I	**Personalisation of Therapies in COVID-19 Associated Acute Respiratory Distress Syndrome, Using Electrical Impedance Tomography**	*J Crit Care Med (Targu Mures)* **2021 Jan**

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	Krauss E et al.	**Evaluation of Regional Pulmonary Ventilation in Spontaneously Breathing Patients with Idiopathic Pulmonary Fibrosis (IPF) Employing Electrical Impedance Tomography (EIT): A Pilot Study from the European IPF Registry (eurIPFreg)**	*J. Clin. Med.* ***2021 Jan***

Objectives: In idiopathic pulmonary fibrosis (IPF), alterations in the pulmonary surfactant system result in an increased alveolar surface tension and favor repetitive alveolar collapse. This study aimed to assess the usefulness of electrical impedance tomography (EIT) in characterization of regional ventilation in IPF.

Materials and methods: We investigated 17 patients with IPF and 15 healthy controls from the University of Giessen and Marburg Lung Center (UGMLC), Germany, for differences in the following EIT parameters: distribution of ventilation (TID), global inhomogeneity index (GI), regional impedance differences through the delta of end-expiratory lung impedance (dEELI), differences in surface of ventilated area (SURF), as well as center of ventilation (CG) and intratidal gas distribution (ITV). These parameters were assessed under spontaneous breathing and following a predefined escalation protocol of the positive end-expiratory pressure (PEEP), applied through a face mask by an intensive care respirator (EVITA, Draeger, Germany).

Results: Individual slopes of dEELI over the PEEP increment protocol were found to be highly significantly increased in both groups ($p < 0.001$) but were not found to be significantly different between groups. Similarly, dTID slopes were increasing in response to PEEP, but this did not reach statistical significance within or between groups. Individual breathing patterns were very heterogeneous. There were no relevant differences of SURF, GI or CGVD over the PEEP escalation range. A correlation of dEELI to FVC, BMI, age, or weight did not forward significant results.

Conclusions: In this study, we did see a significant increase in dEELI and a non-significant increase in dTID in IPF patients as well as in healthy controls in response to an increase of PEEP under spontaneous breathing. We propose the combined measurements of EIT and lung function to assess regional lung ventilation in spontaneously breathing subjects.

CLIN	Clarke J et al.	**Prone positioning improves oxygenation and lung recruitment in patients with SARS-CoV-2 acute respiratory distress syndrome; a single centre cohort study of 20 consecutive patients**	*BMC Research Notes* ***2021 Jan***

Objective: We aimed to characterize the effects of prone positioning on respiratory mechanics and oxygenation in invasively ventilated patients with SARS-CoV-2 ARDS.

Results: This was a prospective cohort study in the Intensive Care Unit (ICU) of a tertiary referral centre. We included 20 consecutive, invasively ventilated patients with laboratory confirmed SARS-CoV-2 related ARDS who underwent prone positioning in ICU as part of their management. The main outcome was the effect of prone positioning on gas exchange and respiratory mechanics. There was a median improvement in the PaO2/FiO2 ratio of 132 in the prone position compared to the supine position (IQR 67–228). We observed lower PaO2/FiO2 ratios in those with low (< median) baseline respiratory system static compliance, compared to those with higher (> median) static compliance ($P < 0.05$). There was no significant difference in respiratory system static compliance with prone positioning. Prone positioning was effective in improving oxygenation in SARS-CoV-2 ARDS. Furthermore, poor respiratory system static compliance was common and was associated with disease severity. Improvements in oxygenation were partly due to lung recruitment. Prone positioning should be considered in patients with SARS-CoV-2 ARDS.

CLIN	**Chen R et al.**	**EIT Based Time Constant Analysis to Determine Different Types of Patients in COVID-19 Pneumonia**	*Jarm T et al.(eds): EMBEC 2020, IFMBE Proceedings* ***2020 Nov***

Purpose: To evaluate the lung compliance variation over the course of COVID-19 pneumonia, and to classify the patients into different types described as recruitable and non-recruitable, which lead to different ventilator support treatment.

Method: Two ICU admitted COVID-19 patients, who were mechanically ventilated for more than 7 days, were included into this investigation. During a daily recruitment maneuver - a PEEP trial - they were monitored by Electrical Impedance Tomography (EIT). Deflation time constants were calculated offline from EIT data to determine the type of patient and to observe the transition of different types over the course of pneumonia.

Result: The first patient was recruitable and had the tendency of transition to the other type. The second patient is non-recruitable. Both patients showed low lung compliance, but the first patient started in a better condition (higher compliance).

Conclusion: EIT-based breath-by-breath time constant analysis can classify COVID-19 pneumonia into different classes of patients. The deterioration of lung mechanics can be monitored online by EIT which may help to find proper ventilation treatment.

EDIT	**Bonny V et al.**	**Effect of PEEP decremental on respiratory mechanics, gasses exchanges, pulmonary regional ventilation, and hemodynamics in patients with SARS-Cov-2-associated acute respiratory distress syndrome**	*Crit Care* ***2020 Oct***

To the editor:

Previous reports of severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2)-related acute respiratory distress syndrome (ARDS) have been highlighting a profound hypoxemia and it is not yet well defined how to set positive end-expiratory pressure (PEEP) in this context [1]. In this report, we describe the effects of two levels of PEEP on lung mechanics using a multimodal approach.

Patients with confirmed laboratory SARS-Cov-2 infection and meeting criteria for ARDS according to the Berlin definition [2] were eligible within the 48 h after intubation. Written informed consent was waived due to the observational nature of the study. …