

# Effect of Early Mobilization from Bed to Wheel Chair on Regional Ventilation Distribution Assessed by Electrical Impedance Tomography in Respiratory Failure Patients

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## Research

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# Abstract

**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 ( $T_{\text{base}}$ : baseline, supine position at the bed,  $T_{30\text{min}}$ : sitting position on the wheelchair after 30min,  $T_{60\text{min}}$ : sitting position on the wheelchair after 60min,  $T_{\text{return}}$ : 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  $T_{60\text{min}}$  (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.  $T_{30\text{min}}$ , vs.  $T_{60\text{min}}$ :  $45.9 \pm 12.1$  vs.  $48.7 \pm 11.6$  vs.  $49.9 \pm 12.6$ ,  $p=0.015$ ) and COV (COV baseline vs.  $T_{30\text{min}}$ , vs.  $T_{60\text{min}}$ :  $48.2 \pm 10.1$  vs.  $50.1 \pm 9.2$  vs.  $50.5 \pm 9.6$ ,  $p=0.003$ ). Besides, there was a significant decrease of GI at  $T_{60\text{min}}$ . Patients in the DR group ( $n=18$ ) had significantly higher oxygenation than the Non-DR group ( $n=23$ ) after early mobilization.  $\text{ROI4}_{T_{\text{base}}}$  was significantly negatively correlated to  $\Delta\text{SpO}_2$  ( $R=0.72$ ,  $p < 0.001$ ). Using a cut-off value of 6.5%,  $\text{ROI4}_{T_{\text{base}}}$  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.

**Trial registration:** Effect of Early Mobilization on Regional Lung Ventilation Assessed by EIT, NCT04081129. Registered 9 June 2019 - Retrospectively registered,

<https://register.clinicaltrials.gov/prs/app/action/SelectProtocol?sid=S00096WT&selectaction=Edit&uid=U00020D9&ts=2&cx=v2cwij>

## Background

ICU patients are recommended to receive protocolized rehabilitation and early mobilization [1]. Early mobilization has been proved to prevent ICU acquired weakness and decrease duration of delirium [2–5]. Some research reported that early mobilization can increase ventilator-free days and prevent postoperative respiratory complications [6–8]. However, other study reported early mobilization did not

show an expected outcome of decreasing mechanical ventilation days [9–11]. Considering the human resources, it is controversial whether all patients with mechanical ventilation need early mobilization. Apart from improvements in strength and functional status, to promote the recovery of lung function is also a main purpose of early mobilization. On one hand, early mobilization can induce body position changing so as to influence the movement of diaphragm [12]. On the other hand, it is still not clear whether early mobilization can really promote lung recruitment in dependent area or not.

Electrical impedance tomography (EIT) is a noninvasive, non-ionizing monitoring system, which can obtain real-time imaging of regional lung ventilation at bedside by monitoring electrical impedance changes of the underlying tissue [13, 14]. EIT has already been used in Positive End Expiratory Pressure(PEEP) titration of acute respiratory distress syndrome (ARDS) patients [15, 16]. To our best knowledge, no one has investigated the change of regional lung ventilation during the process of early mobilization. The aim of the study was to examine whether EIT could identify the impact of early mobilization on pulmonary ventilation distribution, and screen out those patients who benefit more from early mobilization, in line with individualized treatment.

## Patients And Methods

### Patients

This study for human subjects was approved by The Institutional Research and Ethics Committee of the Peking Union Medical College Hospital (JS-1896). Written informed consent was obtained from all patients before enrollment.

Adult critically ill patients with respiratory failure who received early mobilization were enrolled in this study. Inclusion criteria were the following: (1) presentation of respiratory failure-Partial pressure of oxygen/Fraction of inspiration oxygen( $\text{PaO}_2/\text{FiO}_2$ ) $\leq 300$ , oxygen saturation( $\text{SpO}_2$ ) $< 92\%$ , or respiration rate( $\text{RR}$ )  $> 25$  bpm. (2) Weaned from mechanical ventilation $\geq 24$ h. (3) need to carry out early mobilization according to patient's condition (e.g. ICU duration $\geq 1$  week, high risk of respiratory complication). Patients were excluded from the study if they were aged  $< 18$  years, were pregnant, had a body mass index (BMI) over  $50 \text{ kg/m}^2$ , had ribcage malformation, had any contraindication against using EIT monitoring (automatic implantable cardioverter defibrillator, chest skin injury, etc.), or had any contraindication against early mobilization (hemodynamic instability,  $\text{FiO}_2 \geq 60\%$ , arrhythmia, etc).

### Physiological measurements

We collected baseline data at enrollment, including age, sex, ICU duration, days of intubation, type of surgery. Respiratory parameters like RR,  $\text{SpO}_2$ ,  $\text{FiO}_2$ , Tidal volume, and hemodynamic parameters, including heart rate (HR), mean arterial pressure (MAP) were obtained at different time points.

# Experimental protocol

Participants went through early mobilization as sitting on the wheel chair. The patient's condition before early mobilization was defined as baseline, with supine position on the bed. Then patients were moved from bed to wheelchair and sitting for 1 hour. After that, patients will return to supine position on the bed. During this movement, patients had EIT belt fixed on their chest and monitoring regional lung ventilation at 4 time points ( $T_{\text{base}}$ : baseline, supine position before early mobilization,  $T_{30\text{min}}$ : sitting position on the wheelchair for 30min,  $T_{60\text{min}}$ : sitting position on the wheelchair for 60min,  $T_{\text{return}}$ : return to supine position on the bed after early mobilization.) Moreover, patients were spontaneous breathing with fixed  $\text{FiO}_2$  during the procedure.

## EIT measurements

EIT measurements were performed with PulmoVista500 (Dräger Medical, Lübeck, Germany). During the protocol, a silicone EIT belt with 16 electrodes were attached on the surface of patient's chest in one transverse plane corresponding to the 4th intercostal parasternal space and was then connected to the EIT monitor for bedside visualization. At different positions, we make sure the 16-electrode array was attached to the same level on the chest surface, so that the lung ventilation is comparable. EIT evaluates lung ventilation by collecting potential differences and the known excitation currents in a  $32 \times 32$  pixel matrix [17]. Each scan pixel demonstrates the instantaneous relative local impedance change compared with a reference state of local impedance. The stimulation frequency and amplitude were adjusted automatically by the EIT device to minimize the influence of background noise. EIT measurements were continuously performed at 20 Hz. In addition, the data were digitally filtered using a low-pass filter with a cutoff frequency of 0.67 Hz to eliminate cardiac-related impedance changes. EIT data were analyzed by offline computer program.

## Analysis of EIT data

The EIT data of 2 minutes at baseline and under different time points were acquired. Tidal images were calculated as the difference images between end-inspiration and end-expiration. An average of 2-min tidal images was calculated at each position to minimize the influence of spontaneous breathing. Mean tidal images were divided into four symmetrical, non-overlapping ventral-to-dorsal horizontal regions of interest (ROIs), ranging from the gravity-independent area to the gravity-dependent area, namely, the ventral (ROI1), mid-ventral (ROI2), mid-dorsal (ROI3) and dorsal (ROI4) regions.

The global inhomogeneity (GI) index can indicate the overall change in inhomogeneity of ventilation and the status of local lung distribution [18]. In brief, the sum of differences between individual pixels to average value was calculated. This sum value was normalized to the amplitude of impedance tidal variation. A lower GI index value is related to a better ventilation homogeneity.

The center of ventilation (CoV) describes the weighted geometrical center of the ventilation distribution [19-21]. When most of the tidal ventilation distributes to the dependent lung region, this results in a higher CoV value.

Patients were divided into two groups: (1) Dependent region recruited group (DR group): ventilation distribution of  $\Delta ROI(3+4)/ROI(3+4)_{T_{baseline}} \geq 15\%$ , (2) Dependent region not-recruitment group (Non-DR group): ventilation distribution  $\Delta ROI(3+4)/ROI(3+4)_{T_{baseline}} < 15\%$ , ( $\Delta ROI(3+4) = ROI(3+4)_{T_{60min}} - ROI(3+4)_{T_{baseline}}$ )

## Statistical analysis

Statistical analysis was measured with SPSS 23.0 (IBM, Armonk, NY) and Prism 7 (GraphPad Software, San Diego, California, USA).

Normal distribution was assessed with Kolmogorov-Smirnov normality test. Normally distributed results are presented as mean  $\pm$  SD whereas non-normally distributed results are presented as median (25th–75th percentile). The Mann–Whitney test was used for comparisons of groups (recruitment group VS not-recruitment group). Comparisons of the trends of the related parameters according to the different positions were performed using a General Linear Model Repeated Measures (GLMRM)[22]. This model is an extension of the classical ANOVA, which allows handling both fixed effect (different position) and random effect (patient). GLMRM takes into account the correlation between multiple measurements on one patient and thus the estimated marginal means were adjusted for the covariates and the trends of related EIT parameters corresponding to the different position. When Mauchly's test of sphericity is not demanded ( $p < 0.05$ ), Epsilon (Greenhouse-Geisser) was used for the corrected test. All statistics were two-tailed, and a p value of less than 0.05 was considered to be significant.

## Results

From Jan 2019 to Jan 2020, this study has enrolled 41 patients. The main characteristics of the patients are summarized in Table 1. The mean patient age was  $64.3 \pm 14.1$ , and 33/41 (80%) were men. 9/41 (22%) of patients had tracheotomy. The mean days of ICU duration was  $14.3 \pm 13.3$ .

Table 1  
Main characteristics of the study population

Characteristics	Data
Age, years	64.3±14.1
Male sex,n(%)	33(80.5)
BMI, kg/m <sup>2</sup>	21.3±3.7
APACHE-II	11.5±3.6
PaO <sub>2</sub> /FiO <sub>2</sub> ,mmHg	247.3±43.5
PaCO <sub>2</sub> , mmHg	40.2±5.7
Cardiosurgery,n(%)	12(29.2)
Preexisting COPD,n(%)	3(7.3)
Septic shock,n(%)	15(36.6)
ARDS,n(%)	11(26.8)
ICU length of stay, days	14.3±13.3
Abbreviations: <i>ARDS</i> Acute respiratory distress syndrome, <i>COPD</i> Chronic Obstructive Pulmonary Disease.	
Data are given as mean ± SD	

## Effects of early mobilization on regional lung ventilation distribution

The trend of ROI4 (dorsal region) significantly increased ( $p=0.01$ ) after early mobilization, but ROI 1-3 showed no significantly difference during study phases. Moreover, GI significantly decreased( $p=0.038$ ) and COV significantly increased( $p=0.047$ ) at  $T_{60\text{min}}$  compared to baseline (Fig. 1).

## Effects of early mobilization on respiratory and hemodynamic parameters

As for respiratory parameters, a significant increase was observed in SpO<sub>2</sub>( $p=0.045$ ) and RR( $p=0.001$ ). Besides, Heart rates has significantly increased after early mobilization( $p=0.011$ ). But MAP remained stable over all study phases. (Table 2)

Table 2  
Changes of respiratory and hemodynamics parameters at different time points

	T <sub>base</sub>	T <sub>30min</sub>	T <sub>60min</sub>	T <sub>return</sub>	Trend- <i>p</i>	Mauchly's test of sphericity <i>p</i> value
<b>HR,</b> <b>beats/min</b>	85.5±11.6	89.3±14.9	90.2±14.6	87.2±12.5	0.011	0.021
<b>MAP,</b> <b>mmHg</b>	82.4±11.3	82.4±11.9	84.5±11.7	84.0±12.0	0.491	0.060
<b>SpO<sub>2</sub>,%</b>	90.6±2.7	91.8±1.9	92.9±1.6	91.0±2.3	0.045	0.580
<b>RR</b>	19.5±4.8	22.3±5.2*	22.7±5.7*	21.0±4.8	0.001	0.027
<p>Abbreviations: <i>HR</i> Heart rate, <i>MAP</i> Mean arterial pressure, <i>SpO<sub>2</sub></i> Peripheral oxygen saturation, <i>RR</i> Respiratory rate</p> <p>T<sub>base</sub>: supine position baseline, T<sub>30min</sub>: sitting position for 30min, T<sub>60min</sub>: sitting position for 60min, T<sub>return</sub>: return to supine position from sitting position</p> <p><i>p</i> value by General Linear Model Repeated Measures</p> <p>Data are given as mean ± SD</p> <p>*<i>P</i> &lt; 0.05</p>						

## Relationship between $\Delta$ ROI 3+4 and $\Delta$ SpO<sub>2</sub>, ROI 4<sub>(base)</sub> and $\Delta$ ROI 3+4, ROI 4<sub>(base)</sub> and $\Delta$ SpO<sub>2</sub>

Regarding the changes, we found that  $\Delta$ ROI(3+4)(ROI(3+4) at T<sub>60min</sub>-ROI(3+4) at T<sub>base</sub>) and  $\Delta$ SpO<sub>2</sub>(SpO<sub>2</sub> at T<sub>60min</sub>- SpO<sub>2</sub> at T<sub>base</sub>) were positively related (R=0.71, *p* < 0.001). Moreover, ROI 4<sub>(base)</sub> (ROI 4 at T<sub>base</sub>) was negatively related to  $\Delta$ SpO<sub>2</sub> (R=0.72, *p* < 0.001 and  $\Delta$ ROI(3+4) (R=0.62, *p*=0.038). (Fig.2)

## Difference between DR and Non-DR groups

18 patients could be categorized to the DR group, and 23 patients to the Non-DR group. Baseline characteristics of two groups are compared in Table 3. There were no significant differences in age, PaO<sub>2</sub>/FiO<sub>2</sub>, HR, RR and days of ICU duration between these two groups at baseline.

Changes of respiratory and hemodynamic parameters in these two groups during study phases are shown in Table 4. There is a significant increase of SpO<sub>2</sub> in DR group, while there is no significant

difference in Non-DR group after early mobilization.

Table 3

Comparison baseline data in recruitment group (DR group) and not-recruitment group (Non-DR group).

Variables	DR group N=18	Non-DR group N=23	p
Age, years	63.8±13.2	64.5±14.3	0.481
Male sex,n(%)	14(77.8)	19(82.6)	0.709
BMI, kg/m <sup>2</sup>	21.2±4.3	22.0±3.8	0.567
APACHE-II	11.8±3.2	11.2±4.5	0.630
ICU length of stay, days	15.3±4.2	13.8±2.1	0.345
PaO <sub>2</sub> /FiO <sub>2</sub> , mmHg	233.5±45.1	256.2±56.2	0.162
PaCO <sub>2</sub> , mmHg	39.8±7.2	40.1±4.5	0.515
ROI 1	14.2±11.6	12.8±8.0	0.833
ROI 2	43.0±11.7	38.9±11.7	0.212
ROI 3	36.9±11.7	40.8±14.8	0.408
ROI 4	5.9±4.0	7.5±4.4	0.043
HR, beats/min	83.2±8.4	87.2±13.4	0.124
MAP, mmHg	80.8±11.3	83.3±11.2	0.782
RR	19.7±4.1	19.2±5.2	0.620
Abbreviations: <i>HR</i> Heart rate, <i>MAP</i> Mean arterial pressure, <i>SpO<sub>2</sub></i> Peripheral oxygen saturation, <i>RR</i> Respiratory rate			
<i>DR group</i> : Dependent region recruited group, <i>Non-DR group</i> : Dependent region non-recruited group			
Data are given as mean ± SD			
* <i>P</i> < 0.05			

Table 4

Subgroup analysis of changes of respiratory and hemodynamics parameters at different time points

	T <sub>base</sub>	T <sub>30min</sub>	T <sub>60min</sub>	T <sub>return</sub>	Trend-p	Mauchly's test of sphericity p value
<b>SpO<sub>2</sub>,%</b>						
<b>DR group</b>	90.8±3.1	92.6±2.1	93.2±1.3	90.4±2.5	0.035	∞0.0001
<b>Non-DR group</b>	92.1±2.3	91.1±1.9	92.2±1.3	92.3±2.2	0.567	∞0.0001
<b>MAP, mmHg</b>						
<b>DR group</b>	80.8±11.3	79.5±7.8	82.5±9.3	80.6±11.7	0.508	0.072
<b>Non-DR group</b>	83.3±11.2	84.4±16.9	85.8±13.1	86.1±11.8	0.663	0.112
<b>HR, beats/min</b>						
<b>DR group</b>	83.2±8.4	83.7±8.1	84.3±8.2	82.7±7.6	0.342	0.017
<b>Non-DR group</b>	87.2±13.4	90.4±17.3	94.6±16.7	90.6±14.2	∞0.0001	0.170
<b>RR</b>						
<b>DR group</b>	19.7±4.1	21.4±4.6	21.7±4.9	21.1±4.8	0.011	0.071
<b>Non-DR group</b>	19.2±5.2	22.7±5.7	23.2±6.3	20.7±4.9	∞0.0001	0.386
<b>GI</b>						
<b>DR group</b>	0.78±0.34	0.79±0.36	0.73±0.33	0.74±0.24	0.733	0.005
<b>Non-DR group</b>	0.86±0.45	0.78±0.30	0.72±0.37	0.95±0.76	0.144	0.0001
<b>COV</b>						
<b>DR group</b>	46.2±10.5	50.4±11.0	50.1±10.0	48.2±10.7	0.0001	0.441
<b>Non-DR group</b>	49.7±10.3	49.7±9.1	50.9±9.3	50.5±13.0	0.689	0.0001

Abbreviations: *HR* Heart rate, *MAP* Mean arterial pressure, *SpO<sub>2</sub>* Peripheral oxygen saturation, *GI* Global inhomogeneity, *COV* Centre of ventilation.

$T_{\text{base}}$ : supine position baseline,  $T_{30\text{min}}$ : sitting position for 30min,  $T_{60\text{min}}$ : sitting position for 60min,  $T_{\text{return}}$ : return to supine position from sitting position

$p$  value by General Linear Model Repeated Measures

Data are given as mean  $\pm$  SD

\* $P < 0.05$

## Using ROI 4<sub>(base)</sub> to distinguish DR patients

If we use ROI 4 at baseline as a predictor to distinguish DR group from Non-DR group, ROC curve of ROI 4<sub>(base)</sub> diagnostic value was showed in Figure 3. The best cut-off for ROI 4<sub>(base)</sub> is 6.5%, which means that in patients with an initial ROI 4<sub>(base)</sub>  $\geq$  6.5%, early mobilization may improve oxygenation and prefer to be performed. The specificity is 79.2%, while the sensitivity only 58.8%. Area under curve is 0.806(95%CI, 0.677-0.936).

## Discussion

In this study, we focused on body position change from supine to sitting on the wheelchair. We found that 1) early mobilization can induce lung recruitment in some but not all patients. 2) EIT is feasible in monitoring regional ventilation distribution change during early mobilization. 3) ROI 4<sub>(base)</sub> was negatively related to  $\Delta\text{SpO}_2$  and lung recruitment in the dependent regions, which suggested that baseline ventilation distribution in the most dorsal regions might predict the recruitment responsiveness of early mobilization.

## Effects of early mobilization on lung recruitment

As shown in previous study, early mobilization may introduce lung recruitment to prevent postoperative respiratory complications and increase ventilator-free days [6-8]. But controversial results were found in other studies [9, 10]. In our study, early mobilization can induce lung recruitment in gravity-dependent lung area in some, but not in all patients, which explained the controversial results in previous studies.

Furthermore, we divided all patients into two types:(a) in DR group, patients showed recruitment in the dorsal region and better oxygenation after early mobilization. (b) in Non-DR group, patients didn't take advantage from early mobilization with no difference in oxygenation and recruitment. Thus, patients classified as type DR may have a greater potential for recruitment, which indicates that early mobilization therapy may benefit these patients and is recommended. Patients classified as type Non-DR may have limited potential for recruitment and should be used cautiously.

# EIT on regional lung ventilation

Early mobilization influences regional lung ventilation by body position changing. Previous researches have used EIT to monitor ventilation improvement during body position changing [23-27] and proved EIT's feasibility. Hough *et al* [24] confirmed that body position changes might influence regional ventilation distribution in infants, whereas Pauline S *et al* [25] reported no difference between lateral and supine positioning. Riedel *et al* [26] investigating supine and prone position by EIT and found ventilation in dependent lung region increased in the prone position.

In this study, we used EIT to monitor regional ventilation change from supine to sitting position. The results show that ROI<sub>4</sub>, CoV and GI improved in sitting position, which means more gas into dorsal region and ventilation became more homogenous. This result is in accord with previous study [28, 29]. One study showed that FEV<sub>1</sub> increased when healthy volunteers changed from supine to sitting position [28]. Another study found that sitting position constantly and significantly relieved expiratory flow limitation and auto-positive end-expiratory pressure resulting in a dramatic drop in alveolar pressures in critically ill obese patients under mechanical ventilation [29]. Due to the change of gravity direction and the shift of diaphragm, it was possible that EIT measurement included partially different lung tissue in supine and sitting positions. Nevertheless, the improvement from T<sub>30min</sub> to T<sub>60min</sub> confirmed the improvement of ventilation distribution in sitting position.

## ROI 4<sub>(base)</sub>, SpO<sub>2</sub> and lung recruitment

A previous study showed that early mobilization could improve SpO<sub>2</sub> [30], but may not be applicable to all of ICU patients. In the present study, we found SpO<sub>2</sub> improvement in 78% patients in the DR group (14/18) and only 26% patients have improved SpO<sub>2</sub> in Non-DR group (6/23). In addition, we found that  $\Delta\text{SpO}_2$  and  $\Delta\text{ROI}(3+4)$  were positively related and ROI 4<sub>(base)</sub> was negatively related to  $\Delta\text{SpO}_2$ , which means patients with lower baseline ROI 4 proportion may have higher possibility to get lung recruitment and improved oxygenation after early mobilization. In clinical practice due to limited manpower, position change to sitting isn't easy to carry out for ICU patients. So it will be beneficial to distinguish specific group of patients who would benefit the most from early mobilization. The responsiveness to early mobilization could be partially predicted with ROI 4<sub>base</sub> (Fig. 3).

## Limitations

This study also has some limitations. First, we only monitored one-time of early mobilization for 1 hour and the study period may be not long enough to monitor regional ventilation changing. Second, the sample size might be considered not large enough for subgroup analysis. Third, during the 4 time points, patients need to be moved from supine position from bed to sitting position on wheelchair, although we had conducted it with cautious, the position of 16-electrode belt of EIT might be still slightly shifted. So

we did not compare the end expiration lung impedance level. Fourth, the threshold used to distinguish recruited and non-recruited groups (15%) was arbitrary and its clinical value needs to be further studied.

## **Conclusion**

Early mobilization can induce lung recruitment in dorsal lung regions and improve oxygenation in some but not all patients. The baseline ventilation distribution in the most dorsal regions might predict the recruitment responsiveness of early mobilization. EIT may be useful to identify patients who could benefit most from early mobilization.

## **Declarations**

## **Ethical Approval and Consent to participate**

The Institutional Research and Ethics Committee of the Peking Union Medical College Hospital approved this study on human subjects. Written informed consent was obtained from the patients' next of kin.

## **Consent for publication**

All authors read and approved the final manuscript.

## **Availability of data and materials**

Not applicable

## **Conflicting interests**

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## **Authors' contributions**

SY and HH prepared the final copy of the manuscript and EIT-images. YC and SY performed the EIT examination and obtained patient's consent. HH, SY, YC, YL and ZZ drafting the manuscript for important

intellectual content and interpretation for data.

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Not applicable.

## Abbreviations

EIT: electrical impedance tomography

T<sub>base</sub>: baseline, supine position at the bed

T<sub>30min</sub>: sitting position on the wheelchair after 30min

T<sub>60min</sub>: sitting position on the wheelchair after 60min

T<sub>return</sub>: return to supine position on the bed after early mobilization

GI: global inhomogeneity

CoV: center of ventilation

ROI: regions of interest

DR: Dependent region recruited group

Non-DR: Dependent region not-recruitment group

AUC: area under curve

PEEP: Positive End Expiratory Pressure

ARDS: acute respiratory distress syndrome

PaO<sub>2</sub>/FiO<sub>2</sub>: Partial pressure of oxygen/Fraction of inspiration oxygen

SpO<sub>2</sub>: oxygen saturation

RR: respiration rate

BMI: body mass index

HR: heart rate

MAP: mean arterial pressure

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## Figures

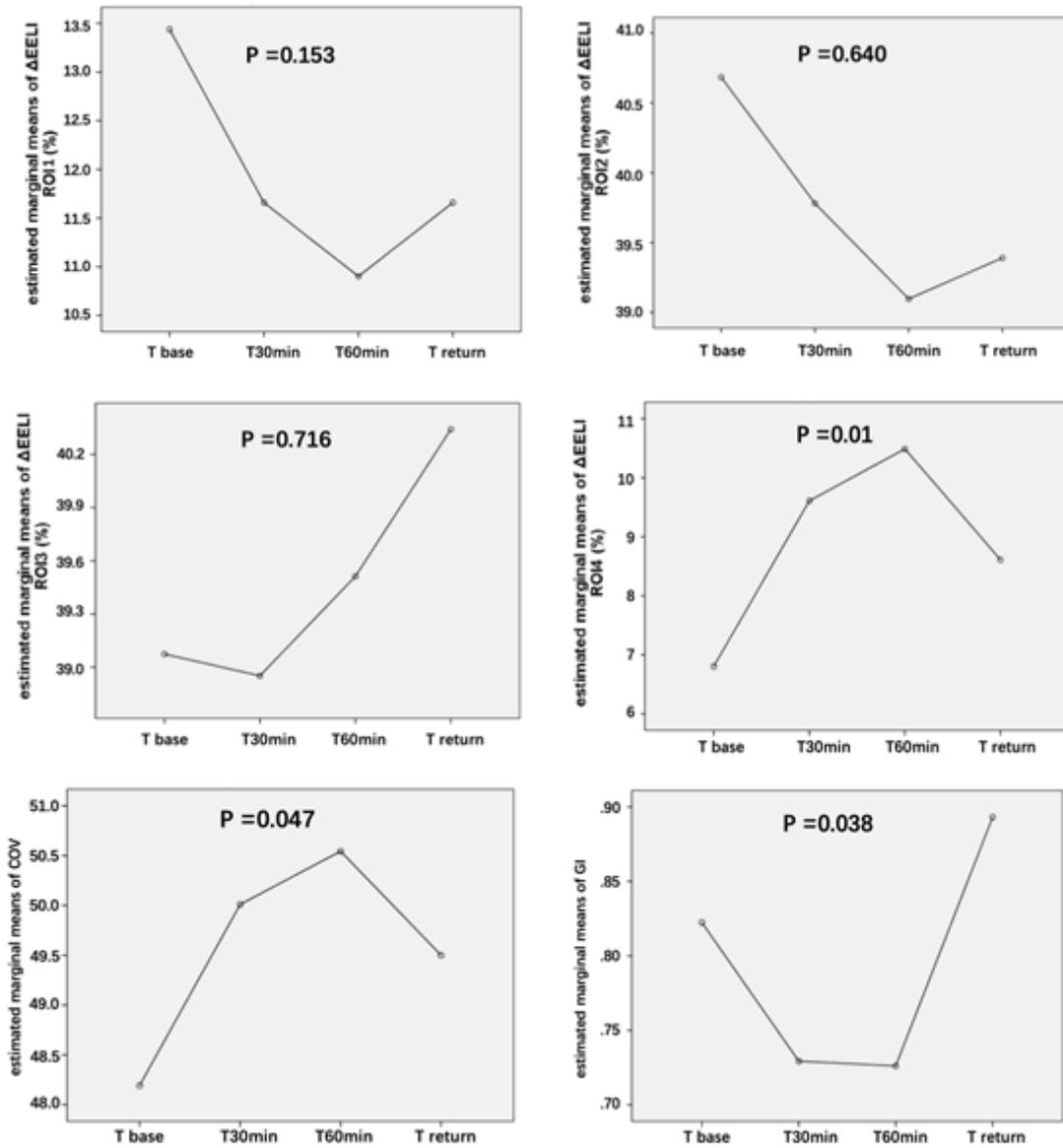


Figure 1

Evolution of estimated marginal means of ROI 1-4, GI and COV at different time points. p value by General Linear Model Repeated Measures

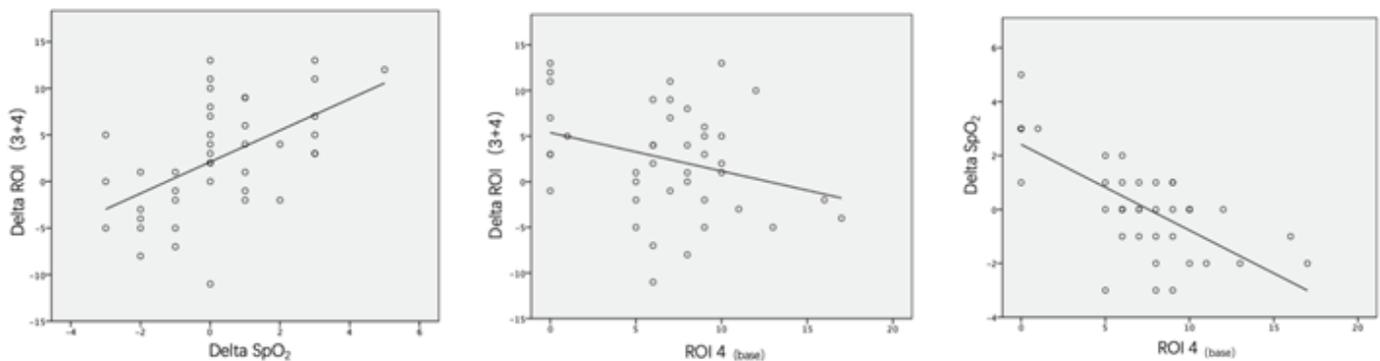
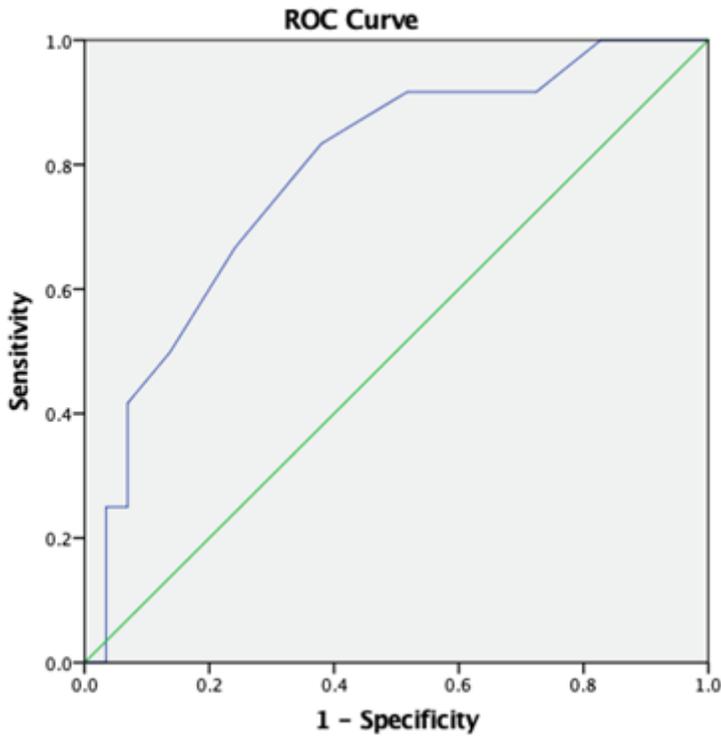


Figure 2

Relationship between  $\Delta$ ROI 3+4 and  $\Delta$ SpO2, ROI 4(base) and  $\Delta$ ROI 3+4, ROI 4(base) and  $\Delta$ SpO2 in 41 patient.  $\Delta$ ROI 3+4 means ROI 3+4 at T60min- ROI 3+4 at Tbase  $\Delta$ SpO2 means SpO2 at T60min- SpO2 at Tbase ROI 4(base) means ROI 4 at Tbase Some data points overlap.



**Figure 3**

The ROC curve of using ROI 4(base) to distinguish DR patients(AUC 0.806 )