# Compressive forces and Computed Tomography-derived Positive End Expiratory Pressure in Acute Respiratory Distress Syndrome

# Supplemental Digital Content Tables

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## Table 1 – Main characteristics of patients divided according to 9% lung recruitability

| | Whole population (51 patients) | Lower recruiters (17 patients) | Higher recruiters (34 patients) | P value |
|---|---|---|---|---|
| Body mass index (Kg/m$^2$) | 27±6 | 27±7 | 27±6 | 0.87 |
| Age (years) | 61±16 | 61±16 | 61±17 | 1.00 |
| Males - n (%) | 38 (75) | 13 (76) | 25 (74) | 0.91 |
| Days elapsed before CT scan | 5±7 | 7±10 | 3±3 | 0.07 |
| ICU survival – n (%) | 30 (59) | 11 (65) | 19 (56) | 0.76 |
| Tidal volume (ml)/Kg ideal body weight (ml/Kg) | 8.2±1.3 | 7.6±0.9 | 8.5±1.4 | 0.01 |
| Respiratory rate (breaths/min) | 17±4 | 19±3 | 16±3 | < 0.01 |
| Plateau pressure (cm H$_2$O) | 18.7±4.2 | 18.2±4.3 | 18.9±4.1 | 0.44 |
| Mean airway pressure (cm H$_2$O) | 10.9±1.5 | 10.6±1.2 | 11.0±1.6 | 0.82 |
| Lung elastance (cm H$_2$O/l) | 20.3±8.1 | 20.3±10.2 | 20.3±7.0 | 0.53 |
| Chest wall elastance (cm H$_2$O/l) | 6.8±4.3 | 6.6±3.7 | 6.8±4.6 | 0.94 |
| Intra-abdominal pressure (cm H$_2$O) | 9±3 | 9±4 | 8±3 | 0.3 |
| PaO$_2$/FiO$_2$ | 144±53 | 157±38 | 137±58 | 0.20 |
| PaO$_2$ (mmHg) | 68±13 | 69±12 | 68±14 | 0.62 |
| FiO$_2$ | 53±19 | 46±13 | 56±20 | 0.06 |
| PaCO$_2$ | 45±7 | 45±7 | 46±7 | 0.89 |
| Physiological dead space (%) | 57±14 | 52±15 | 59±13 | 0.13 |
| Shunt (%) | 41±12 | 34±10 | 44±12 | < 0.01 |
| SaO$_2$ (%) | 91.6±3.9 | 93.6±2.7 | 90.7±4.0 | 0.01 |
| SvO$_2$ (%) | 71.9±7.3 | 71.9±9.2 | 71.9±6.2 | 0.99 |
| Oxygen extraction ratio | 0.22±0.07 | 0.23±0.09 | 0.21±0.06 | 0.41 |
| Cause of lung injury – no (%) | | | | 0.27 |
| Pneumonia | 26 (51) | 6 (35) | 20 (59) | |
| Sepsis | 9 (18) | 4 (24) | 5 (15) | |
| Aspiration | 5 (10) | 2 (12) | 3 (9) | |
| Trauma | 5 (10) | 1 (6) | 4 (12) | |
| Other | 6 (12) | 4 (24) | 2 (6) | |

**Table legend**

The table summarizes the main physiological and CT scan data standardized at PEE5 cm H$_2$O and the CT scan data at 45 cm H$_2$O end-inspiration. Plus-minus values are means ± standard deviation. Because of rounding percentages may not total 100. The body-mass index is the weight in kilogram divided by the square of the height in meters. Normality of variables was checked with the Shapiro-Wilk test. P values were obtained with Student's t-test, Wilcoxon's test or Chi-square test, as appropriate. Days elapsed before CT scan were counted from ICU admission to the CT scan acquistion. Physiological dead space was available in 47 patients, 15 lower recruiters and 32 higher recruiters. The intra-abdominal pressure was measured as intra-bladder pressure injecting 100 ml of normal saline pre-heated at body temperature and was available in 49 patients (14 higher and 31 lower recruiters).

CT = computed tomography; FiO$_2$ = inspired oxygen fraction; ICU = Intensive Care Unit; PaCO$_2$ = arterial partial pressure of carbon dioxide; PaO$_2$ =arterial partial pressure of oxygen; SaO$_2$ = hemoglobin saturation in arterial blood;

$SvO_2$ = saturation in venous blood sampled from a central vein.

**Table 2 – Main CT scan characteristics of patients divided according to 9% lung recruitability**

| CT scan compartment | Airway pressure | Whole population (51 patients) | Lower recruiters (17 patients) | Higher recruiters (34 patients) | P value |
|---|---|---|---|---|---|
| Total tissue (grams) | 5 cm $H_2O$ | 1484±487 | 1351±338 | 1551±538 | 0.12 |
|  | 45 cm $H_2O$ | 1491±484 | 1392±342 | 1540±539 | 0.17 |
| Total gas (ml) | 5 cm $H_2O$ | 1245±588 | 1731±504 | 1002±467 | < 0.0001 |
|  | 45 cm $H_2O$ | 2910±975 | 3325±777 | 2703±1007 | 0.03 |
| Lung density (g/ml) | 5 cm $H_2O$ | 0.55±0.14 | 0.44±0.07 | 0.61±0.13 | < 0.0001 |
|  | 45 cm $H_2O$ | 0.35±0.11 | 0.30±0.05 | 0.37±0.12 | 0.04 |
| Not inflated tissue (%) | 5 cm $H_2O$ | 43±16 | 30±12 | 49±14 | < 0.0001 |
|  | 45 cm $H_2O$ | 27±13 | 25±11 | 28±14 | 0.36 |
| Poorly inflated tissue (%) | 5 cm $H_2O$ | 29±11 | 28±7 | 30±12 | 0.95 |
|  | 45 cm $H_2O$ | 26±12 | 21±5 | 28±13 | 0.12 |
| Well inflated tissue (%) | 5 cm $H_2O$ | 28±14 | 41±9 | 22±11 | < 0.0001 |
|  | 45 cm $H_2O$ | 43±14 | 50±12 | 40±14 | < 0.01 |
| Over inflated tissue (%) | 5 cm $H_2O$ | 0±1 | 1±1 | 0±0 | 0.03 |
|  | 45 cm $H_2O$ | 4±4 | 4±4 | 4±4 | 0.45 |

**Table legend**

The table summarizes the main CT scan data standardized at PEEP 5 cm $H_2O$ and the CT scan data at 45 cm $H_2O$ end-inspiration. Plus-minus values are means ± standard deviation. Because of rounding percentages may not total 100. Normality of variables was checked with the Shapiro-Wilk test. P values were obtained with Student's t-test, Wilcoxon's test or Chi-square test, as appropriate. CT = computed tomography.

**Table 3: CT-derived PEEP and bedside PEEP selection methods**

| | Lower recruiters (17 patients) | Higher recruiters (34patients) | P values |
|---|---|---|---|
| CT-derived PEEP (cm $H_2O$) | 16.3±6.1 | 16.9±4.2 | 1 |
| ExPress method (cm $H_2O$) | 14.9±2.7 | 14.1±3.0* | 1 |
| Stress Index method (cm $H_2O$) | 14.8±4.1 | 13±2.6* | 0.56 |
| Absolute esophageal pressure method (cm $H_2O$) | 12.5±4.3 | 12.6±3.9* | 1 |
| LOV study method (cm $H_2O$) | 10.0±3.6* | 12.2±3.1* | 0.19 |

**Table legend**

Table summarizes the  PEEP values selected in patient classified as lower and higher recruiters according to the median recruitability of a previously published study (9% of total lung tissue). We performed a two-way ANOVA for repeated measures using as dependent variable the PEEP level selected and as factors the PEEP selection method and the patient classification (higher vs lower recruiter). The effect of lung recruitability was not significant (P=0.97) while the effects of the PEEP selection method was significant (P<0.0001);the interaction term as not significant (P=0.06). We performed post-hoc comparisons to assess if the PEEP levels selected were different between higher and lower recruiters and to compare the CT-derived-PEEP with the PEEP values selected with bedside PEEP selection method within lower and higher recruiters. All the p-values of these multiple comparisons were corrected with the Bonferroni's method.

* P< 0.05 vs CT-derived PEEP.

CT = computed tomography; ExPress -  Positive End-**Ex**piratory **Pres**sure Setting in Adults With Acute Lung Injury and Acute Respiratory Distress Syndrome; LOV = Lung Open Ventilation; PEEP = positive end expiratory pressure;

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# Supplemental Digital Content Figures

Massimo Cressoni [2] MD, Davide Chiumello [1] MD , Eleonora Carlesso [2] MSc, Chiara Chiurazzi [2] MD, Martina Amini [2] MD, Matteo Brioni [2] MD, Paolo Cadringher [1] MSc, Michael Quintel [3] MD, Luciano[1]Gattinoni[,2] MD, FRCP

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Patients were divided according to the median lung recruitability of a previously published study which was 9%[1].

**Supplemental Digital Content Figure 1**
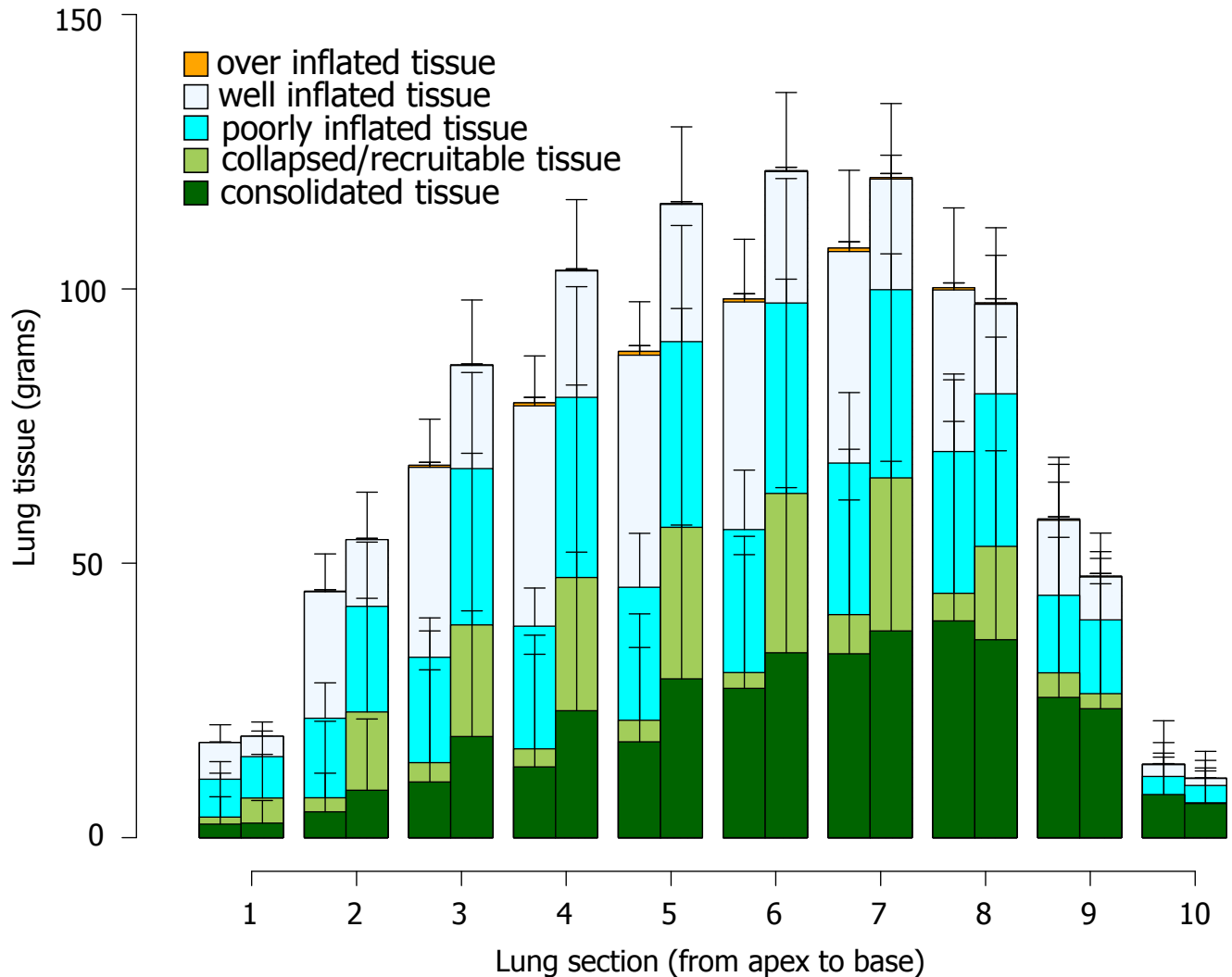


Figure presents the distribution of recruitable tissue (non aerated at PEEP 5 cm $H_2O$ and inflated at 45 cm$H_2O$ airway pressure), consolidated tissue (not aerated both at PEEP 5 cm $H_2O$ and 45 cm $H_2O$ airway pressure), poorly inflated, well inflated and over-inflated tissue higher (coarse pattern) and lower (no pattern) recruiters. Data taken at PEEP 5 cm $H_2O$. PEEP = positive end expiratory pressure.

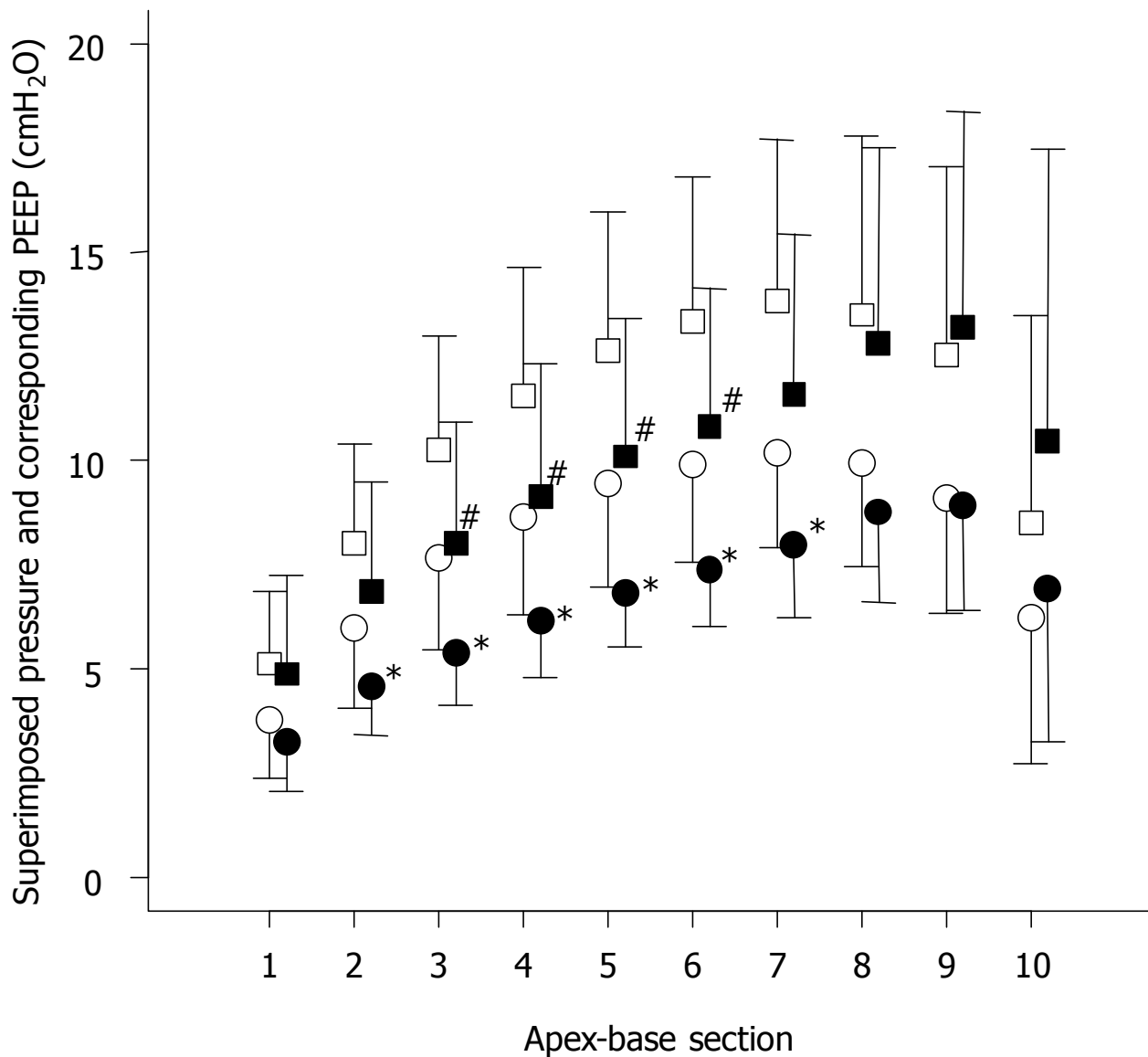**Supplemental Digital Content Figure 2**



Figure presents the superimposed pressure compressing each lung section (circles) and the corresponding PEEP (squares). Black indicates lower recruiters, white higher recruiters. Data taken at PEEP 5 cm $H_2O$. Values are mean and standard deviation. The maximal superimposed pressure in higher and lower recruiters along the sternum-vertebral axis had been compared with two-way ANOVA (P<0.0001 for both the effect of recruiters/non recruiter and sternum-vertebral axis, P=0.01 for interaction) and values of maximal superimposed pressure at each sternum-vertebral level between higher and lower recruiters had been compared with t-test with the Bonferroni correction. The

corresponding CT-derived PEEP in higher and lower recruiters along the sternum-vertebral axis had been compared with two-way ANOVA (P<0.0001 for both the effect of recruiters/non recruiter and sternum-vertebral axis, P=0.01 for interaction). *P<0.05 comparing maximal superimposed pressure between higher and lower recruiters # P<0.05 comparing CT-derived PEEP between higher and lower recruiters.

CT = computed tomography; PEEP = positive end expiratory pressure; ANOVA = analysis of variance.

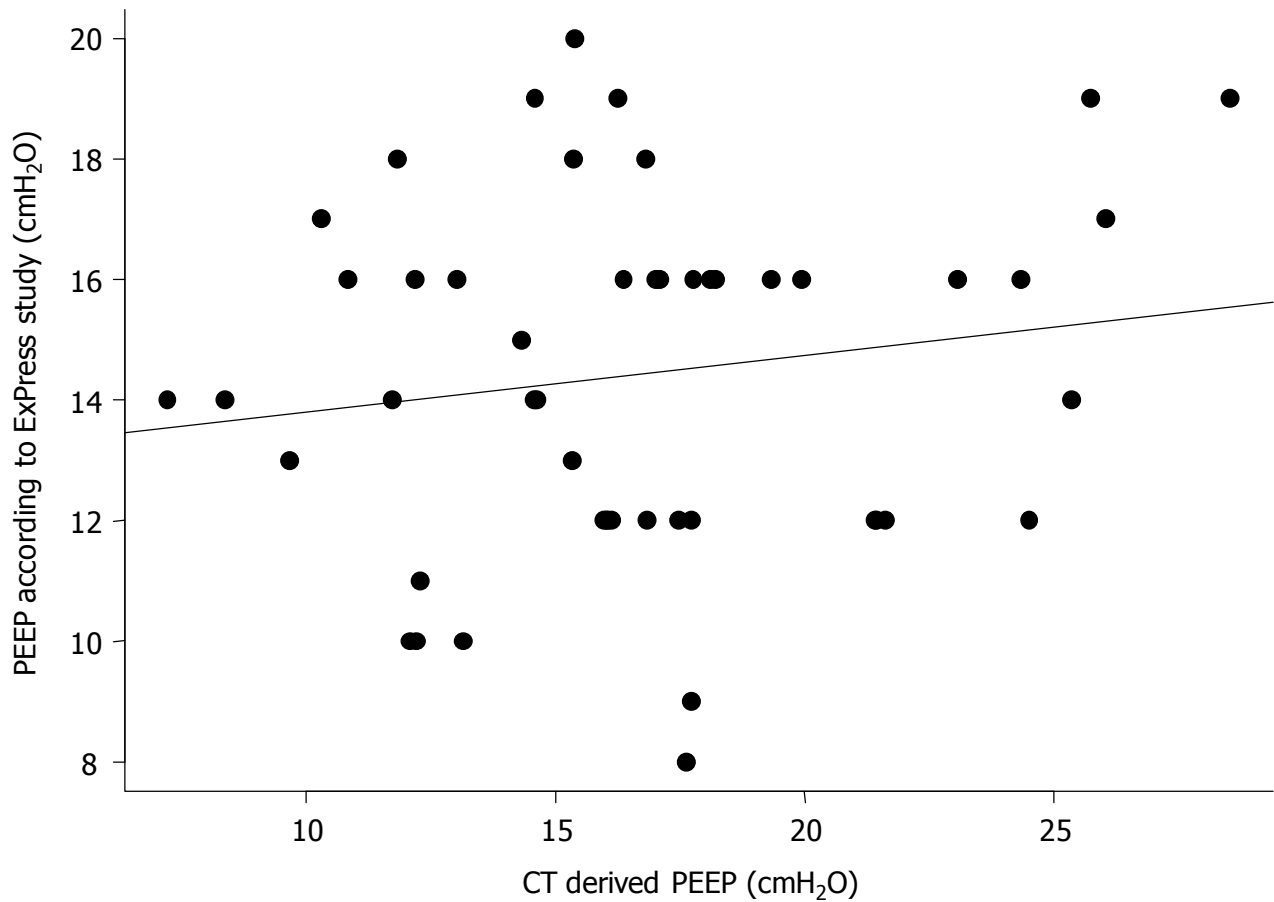**Supplemental Digital Content Figure 3**



Figure presents the relationship between CT-derived PEEP and PEEP selected at bedside with the ExPress study protocol[2]. PEEP selected according to ExPress study protocol (cm $H_2O$) = 12.85 + 0.09 * CT-derived PEEP (cm $H_2O$), $r^2$ = 0.02, P=0.29.

CT = computed tomography; ExPress - Positive End-**Ex**piratory **Pres**sure Setting in Adults With Acute Lung Injury and Acute Respiratory Distress Syndrome; PEEP = positive end expiratory pressure;
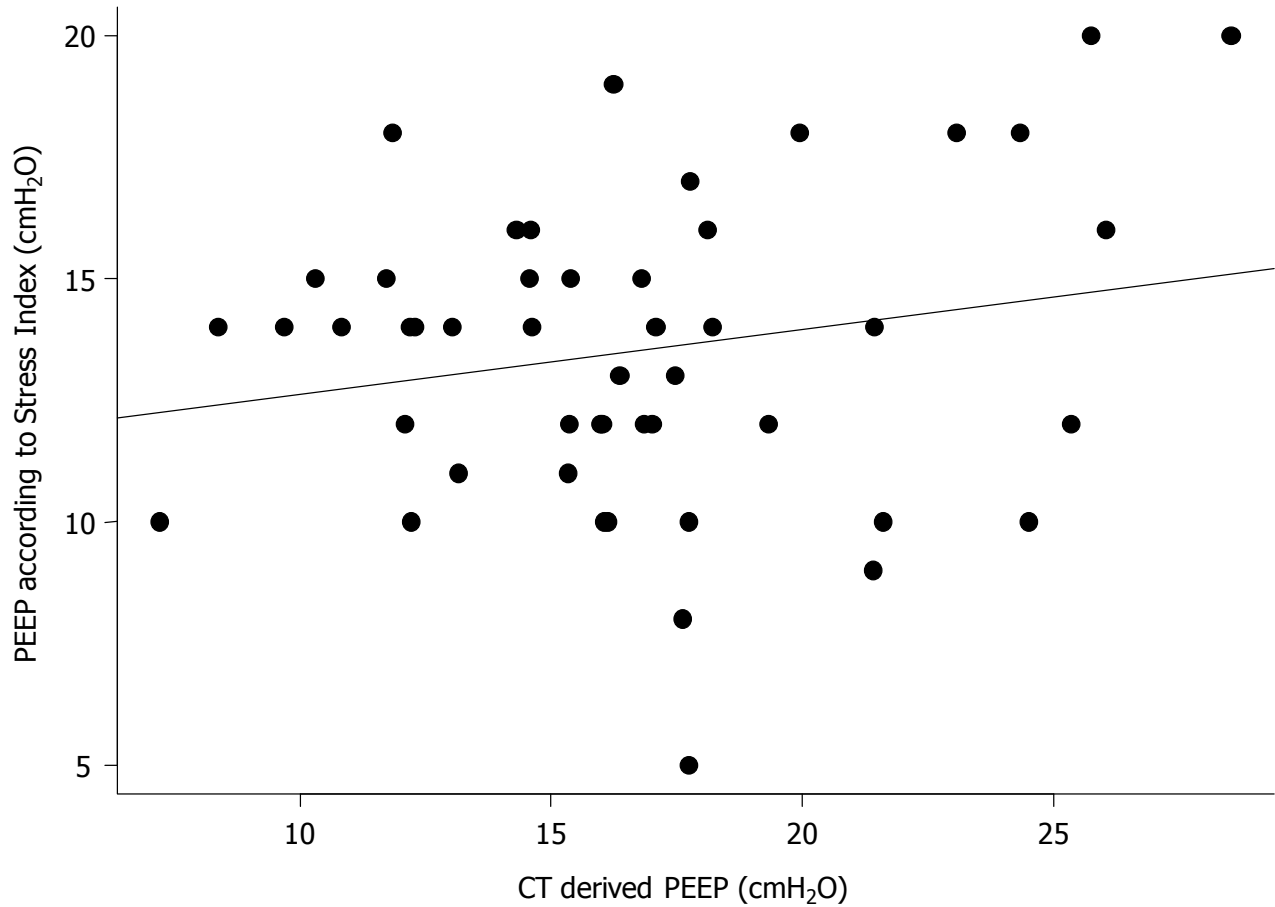
**Supplemental Digital Content Figure 4**



Figure presents the relationship between CT-derived PEEP and PEEP selected at bedside with the Stress Index method[3]. PEEP selected according to Stress Index method ($cmH_2O$) = 11.3 + 0.13 * CT-derived PEEP ($cmH_2O$), $r^2$ = 0.04, p=0.17.

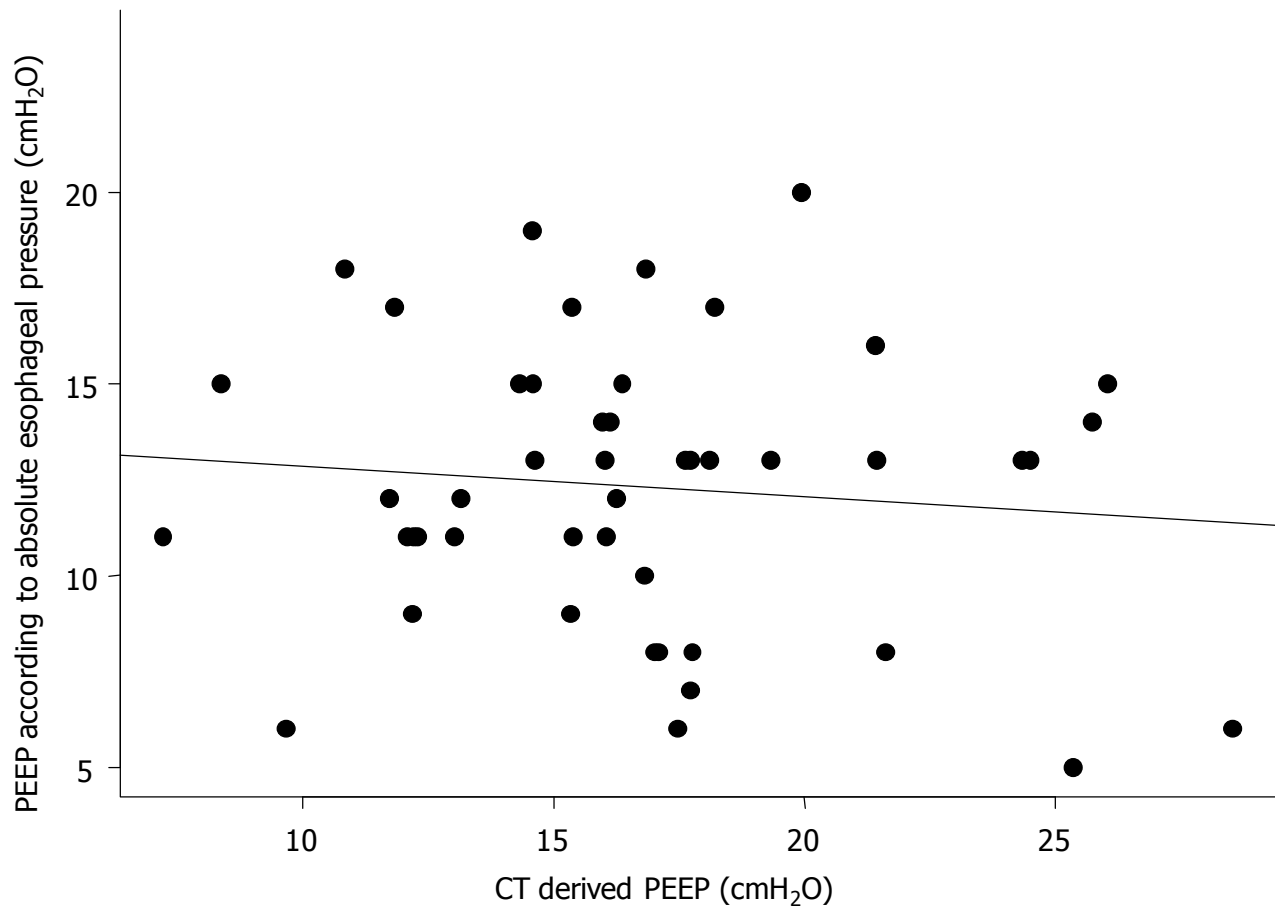CT = computed tomography; PEEP = positive end expiratory pressure;

**Supplemental Digital Content Figure 5**



Figure presents the relationship between CT-derived PEEP and PEEP selected at bedside using the absolute value of esophageal pressure[4]. PEEP selected according to absolute value of esophageal pressure ($cmH_2O$) = 13.6 - 0.08 * CT-derived PEEP (cm $H_2O$), $r^2$ = 0.01, P=0.50.

CT = computed tomography; PEEP = positive end expiratory pressure;
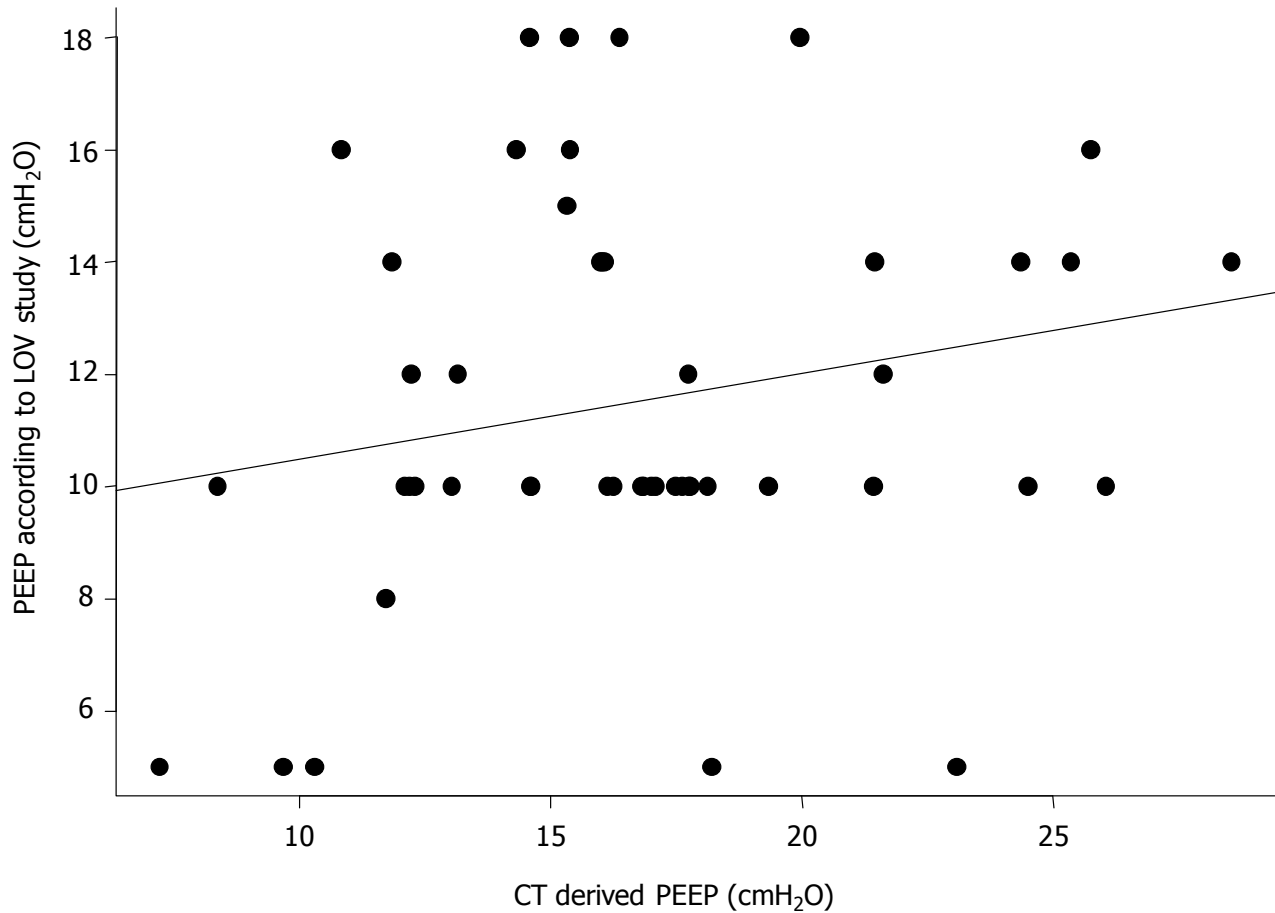
**Supplemental Digital Content Figure 6**



Figure presents the relationship between CT-derived PEEP and PEEP selected at bedside using the method applied in the LOV study[5]. PEEP selected according to LOV study method (cm $H_2O$) = 8.96 + 0.15 * CT-derived PEEP (cm $H_2O$), $r^2$ = 0.04, P=0.15.

CT = computed tomography; LOV = Lung Open Ventilation; PEEP = positive end expiratory pressure;

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