# PEEP IN MECHANICALLY VENTILATED PATIENTS: A CLINICAL PROOF OF CONCEPT

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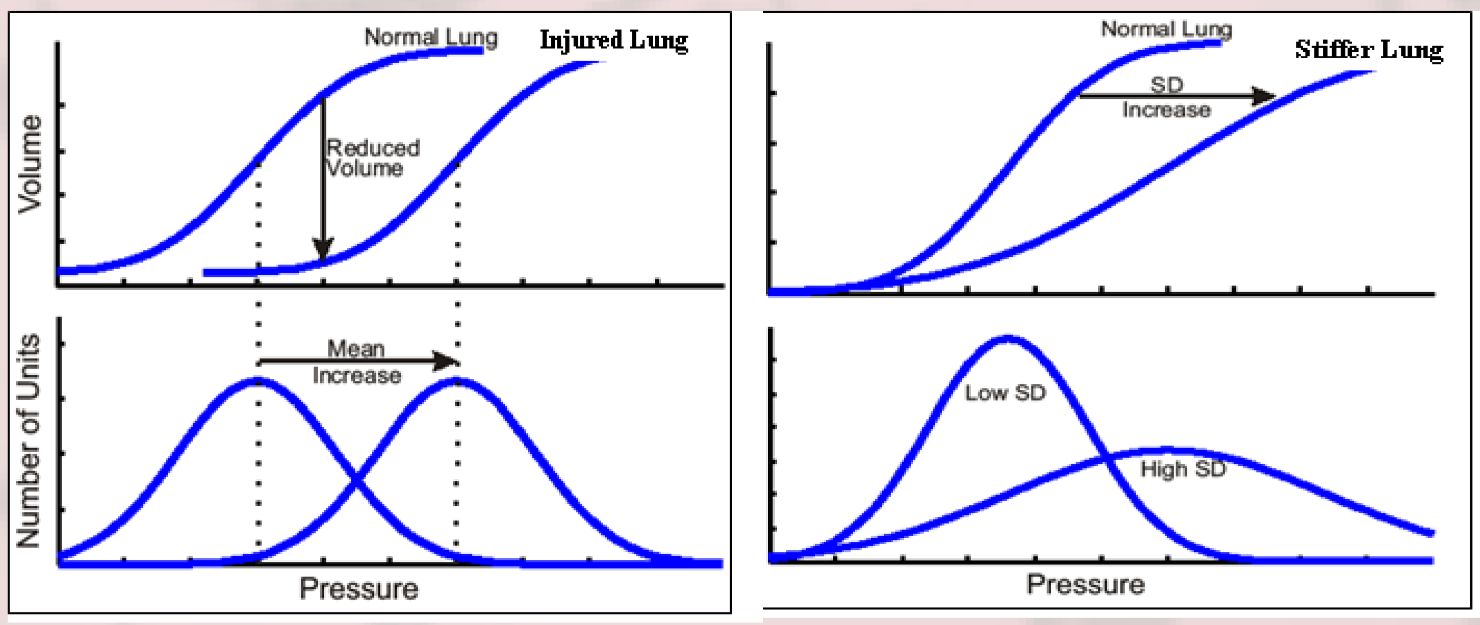
## INTRODUCTION

***OVERVIEW:***
Acute Respiratory Distress Syndrome (ARDS) has mortality rates ranging from 30% to 70% [1]. Patients who are diagnosed with ARDS are often then required to undergo mechanical ventilation in the ICU; a process that can be clinically burdensome and difficult to optimise. This research examines the clinical viability of patient-specific models [2] in pilot clinical trials to assist therapy, optimise patient-specific PEEP, assess the disease state and response over time.

***GOALS:***
Ten patients with acute lung injury or ARDS underwent incremental PEEP recruitment manoeuvres. PV data was measured at increments of 5 $cmH_2O$ and fitted to the recruitment model. Inspiratory and expiratory breath holds were performed to measure airway resistance and auto-PEEP. Optimal PEEP using various metrics were determined for all patients. Two patients underwent multiple recruitment manoeuvres over time and model metrics reflected and tracked the state or their ARDS.

## RECRUITMENT MODEL BASICS

- Alveoli recruitment and de-recruitment controlled by the normally distributed Threshold Opening Pressure (TOP) and Threshold Closing Pressure (TCP), which are assumed to be normally distributed.



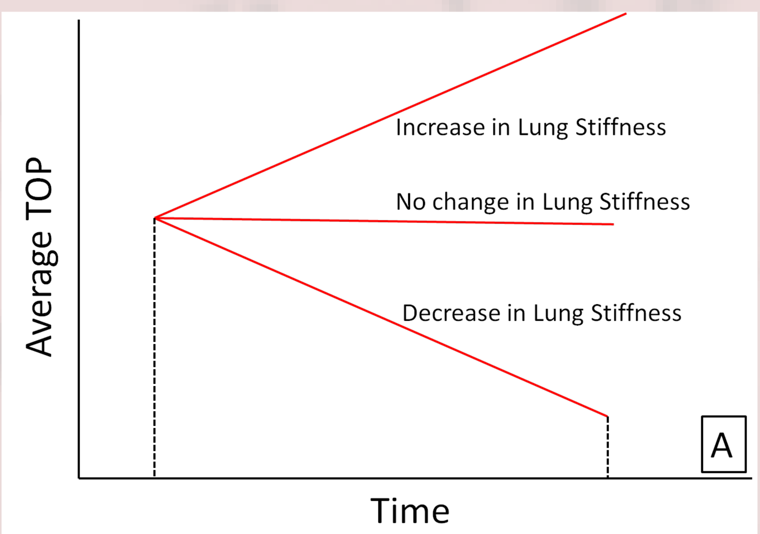

- Model parameters indicate patient recruitability and lung compliance

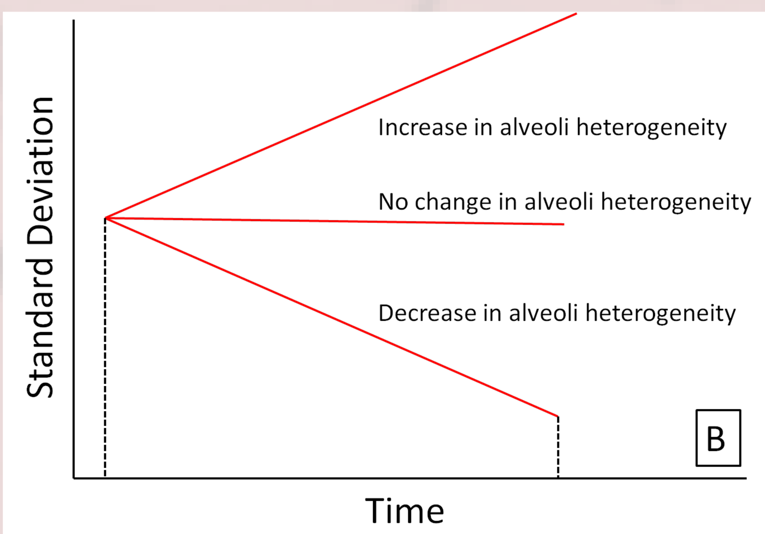
## DISEASE STATE METRICS

- Metrics measured over time to assess disease state

(1) Mean Time Metric

(2) Compliance Time Metric




(3) TOP Gradient Metric

(4) TCP Gradient Metric

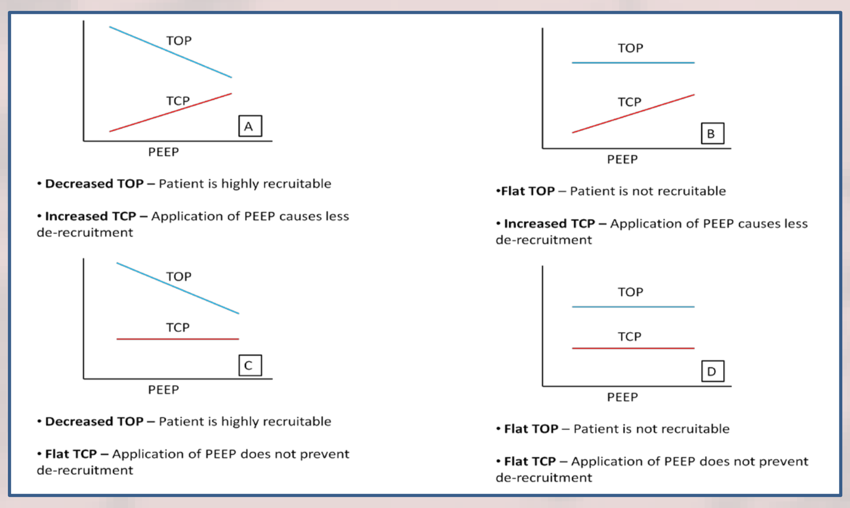
## PEEP SELECTON METRICS

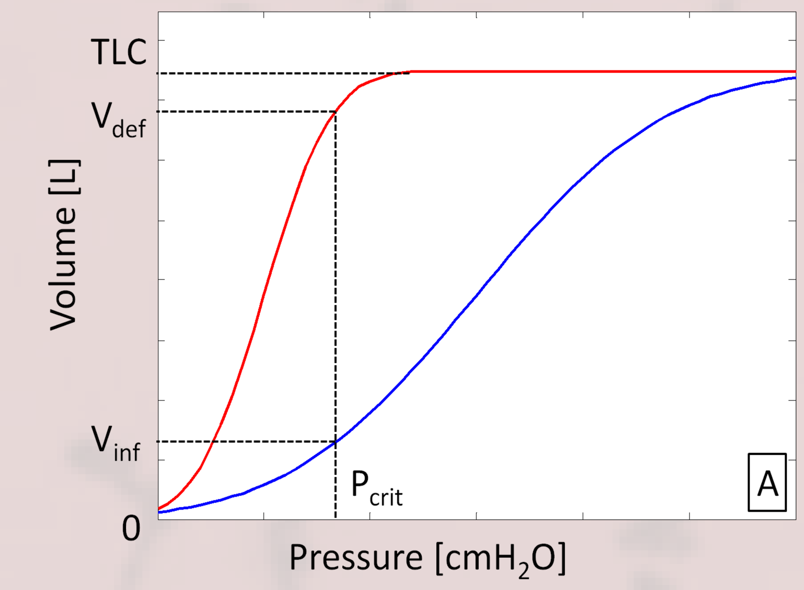
- Metrics to optimise PEEP

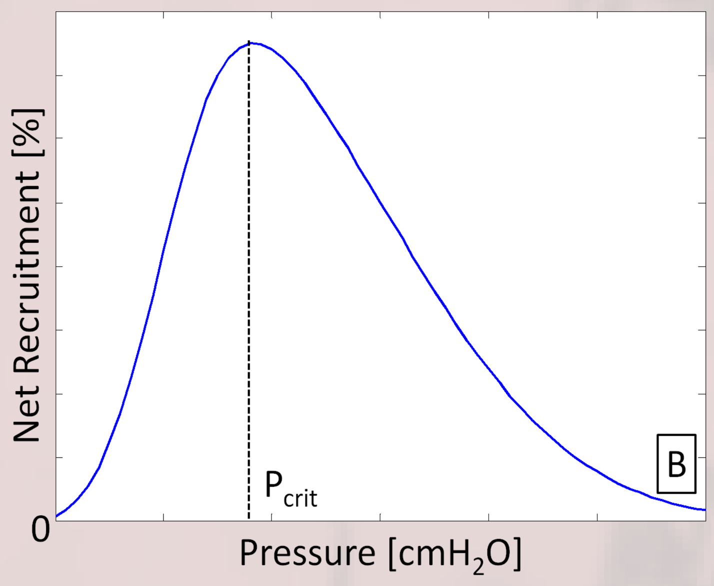
(1)TOP

(2)TCP

(3)Net Recruitment

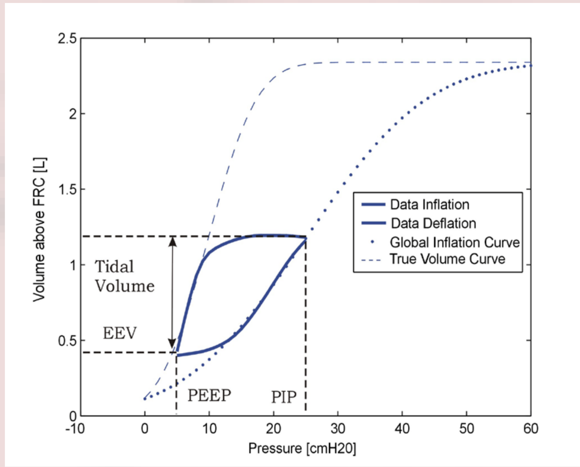


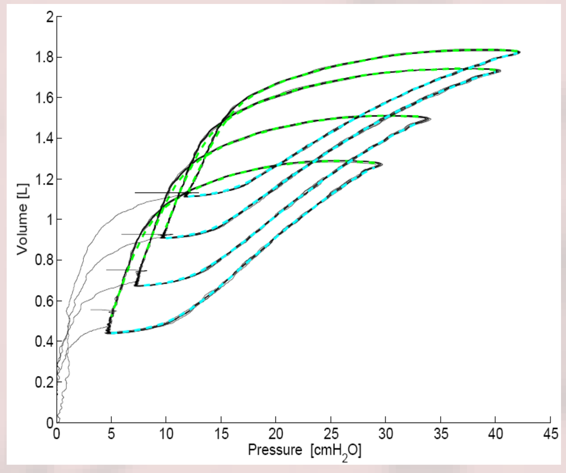


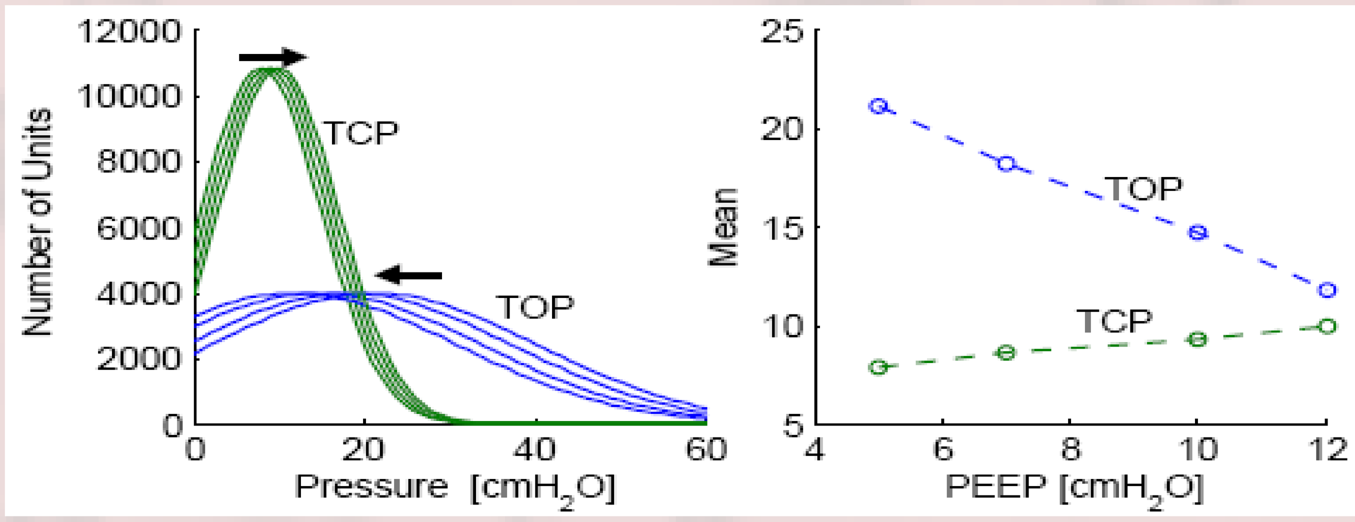




## MODEL FITTING

- Model was validated using PV curves from ten patients





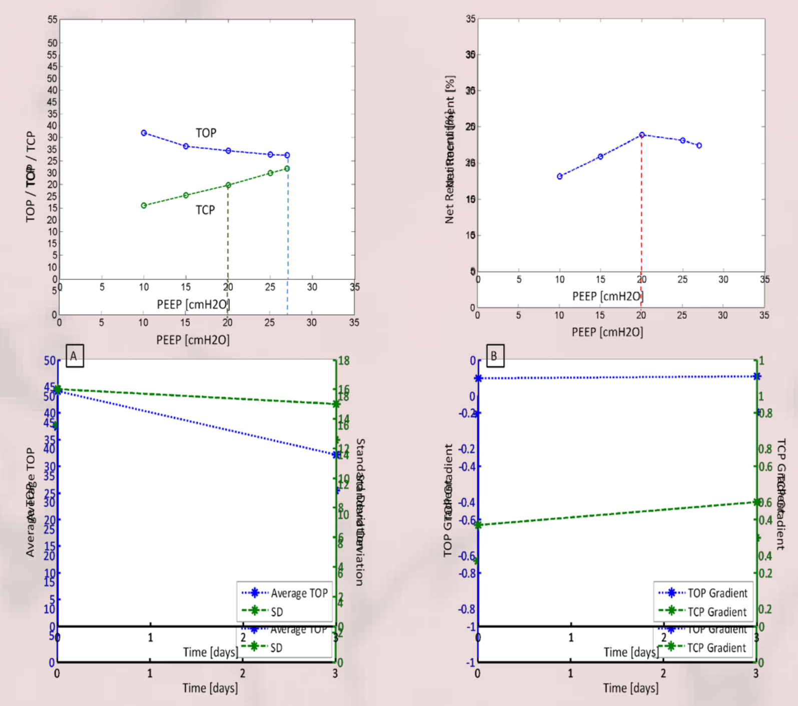

- TOP / TCP average patent response

## CLINICAL VIABILITY & RESULTS

- Three different metrics to help determine optimal PEEP!
  - **TOP** – PEEP chosen such that, any additional pressure does not recruit addition units
  - **TCP** – PEEP chosen such that at least 50% of alveoli remain recruited during expiration. Theoretically could increase PEEP, but this risks overinflating healthy units
  - **Net Recruitment** – Combines the effect of TOP and TCP. PEEP chosen when net recruitment is maximised. Represents the point where additional PEEP does not recruit as many new alveoli and does not keep as many alveoli recruited

| | Clinically Selected PEEP [$cmH_2O$] | Model-Based PEEP Selection [$cmH_2O$] | | |
|---|---|---|---|---|
| | | TOP | TCP | Net Recruitment |
| Patient 1 | 10 | 27 | 20 | 20 |
| Patient 2 | 12 | 15 | 15 | 15 |
| Patient 3 | 10 | 10 | 15 | 20 |
| Patient 4 | 10 | 20 | 20 | 30 |
| Patient 5 | 12 | 20 | 25 | 25 |
| Patient 6 | 11 | 15 | 20 | 20 |
| Patient 7 | 7.5 | 5 | 10 | 10 |
| Patient 8 | 12 | 15 | 20 | 30 |

- Table highlights the optimal PEEP according to model metrics. Clinically selected PEEP is significantly lower than model outputs as a compromise between efficacy and safety



- Top Left - shows the TOP and TCP mean shift for Patient 1. Top Right - shows the net recruitment highlighting optimal PEEP. Bottom – Disease state metrics Patient 5

## CONCLUSIONS

- 3 model-based metrics to optimise PEEP + 4 Metrics to assess disease state over time are presented and assessed
- Mechanical failure / significant compliance changes are captured by the model, however it is limited in assessing COPD patients
- Can be run with software only and using data directly from ventilators – simply, efficient, no extra invasive sensors
- Shows the potential of patient-specific modeling to provide optimised, patient-specific care (e.g. PEEP selection) within an overall protocol based on current, accepted clinical understanding and goals.
- Clearly illustrates how model parameters can create a clear physiological picture of patient-status by capturing physiologically and clinically relevant behaviours. Specifically, underlying physiological condition is represented by model parameters and their change over time (e.g. compliance)

## REFERENCES

[1] Chiumello, D. et al. (2008). *"Lung Stress and Strain during Mechanical Ventilation for Acute Respiratory Distress Syndrome." Am. J. Respir.Crit. Care Med.* 178(4): 346-355.

[2] Sundaresan, A., Yuta, T., Hann, C. E., Geoffrey Chase, J. & Shaw, G. M. (2009). A minimal model of lung mechanics and model-based markers for optimizing ventilator treatment in ARDS patients. *Computer Methods and Programs in Biomedicine,* 95 (2): 166-180.