Assessing Respiratory Mechanics of Reverse-Triggered Breathing Cycles – Case Study of Two Mechanically Ventilated Patients

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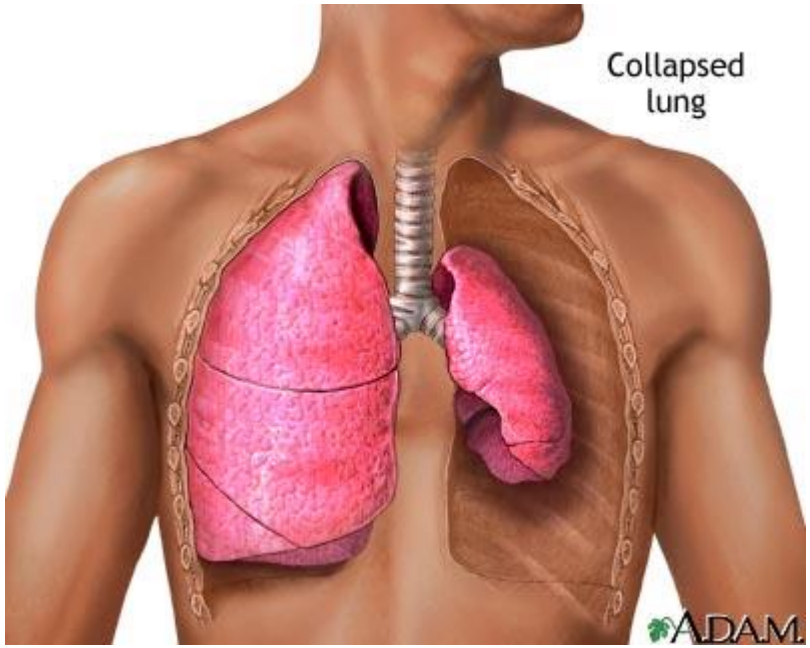
Respiratory Failure and Mechanical Ventilation

- 1965 – Defined by Ashbaugh.
- 1.3 to 34 per 100,000 per year.
- Affecting up to 30% of ICU patients.
- Mortality reported 30~60%.

- Commonly reflects collapsed lung (with collapsed alveoli)



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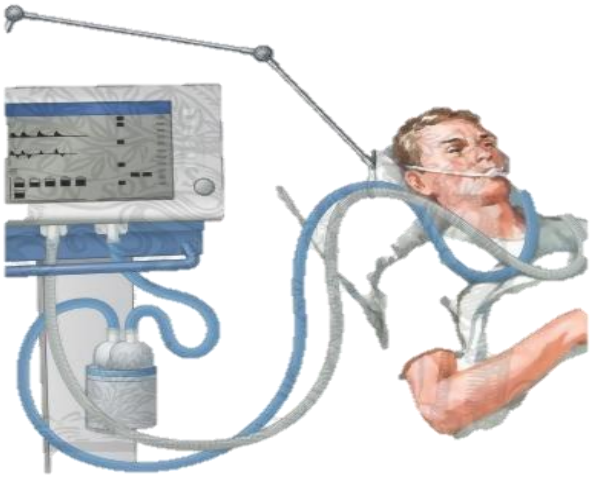

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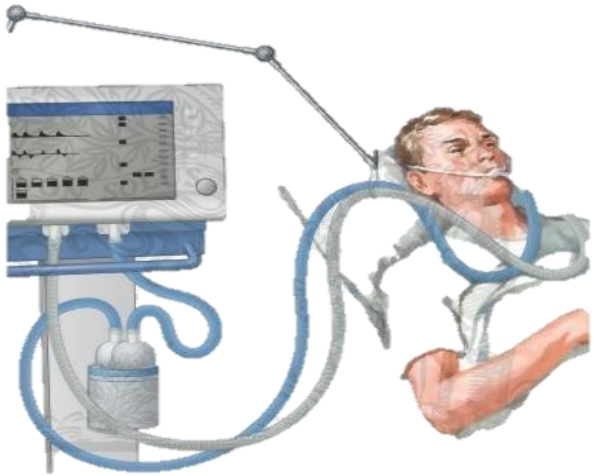
- Can we use respiratory mechanics as a surrogate of lung condition and track it in real-time to guide therapy?



Why are Respiratory Mechanics Relevant?

- ‘Humans are horribly variable’ (Pretty 2012, Dickson et. al. 2014)
- Disease and response is patient-specific.
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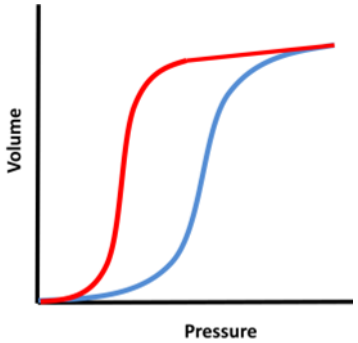
  - *no non-invasive assessment method to assess lung condition*



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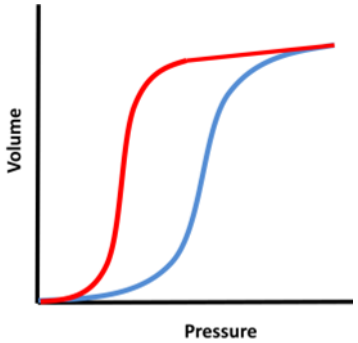
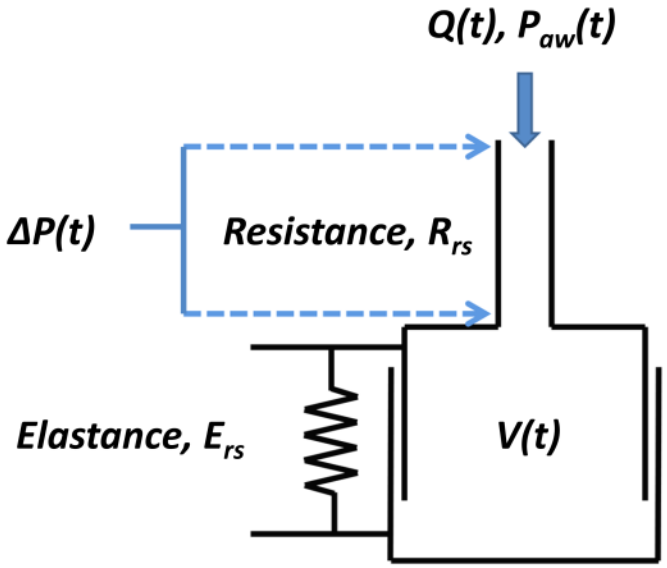


- **Respiratory mechanics can be used to monitor patient condition and guide clinical response in the intensive care unit.**

Single Compartment Lung Model

$$P_{aw}(t) = R_{rs} \cdot Q(t) + E_{rs} \cdot V(t) + P_o$$

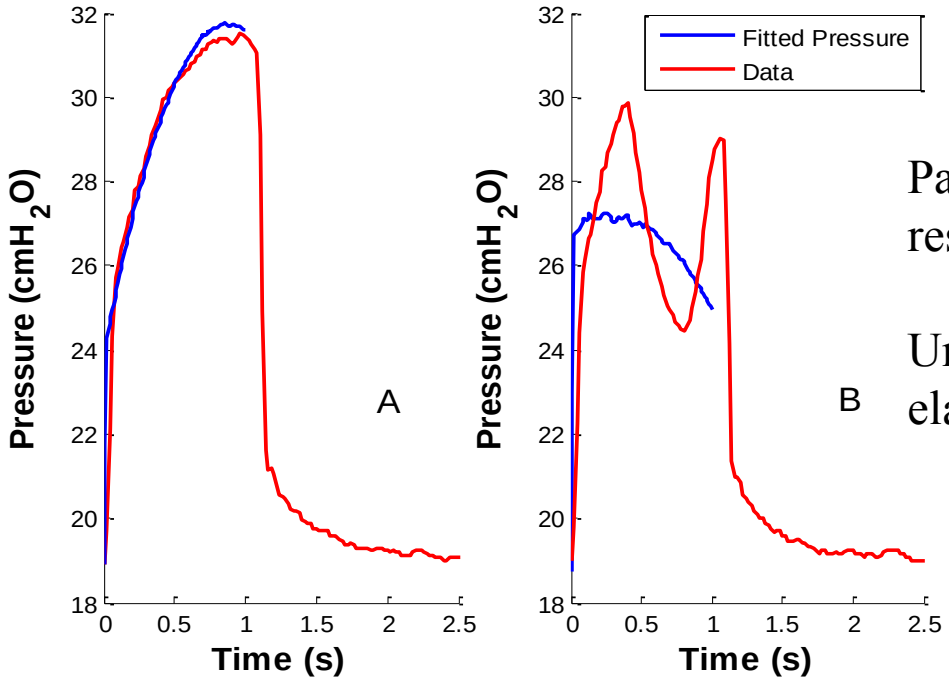


P_{aw}	- Airway pressure
t	- Time
$\boldsymbol{R_{rs}}$	**- Airway resistance**
Q	- Air flow
$\boldsymbol{E_{rs}}$	**- Respiratory System Elastance**
V	- Lung volume
P_0	- Offset pressure (PEEP)

- Fitting the model to pressure and flow data supplies real-time respiratory **elastance** and airway resistance.

The Problem

- Patient effort during ventilator triggered breaths causes anomalies in pressure profiles

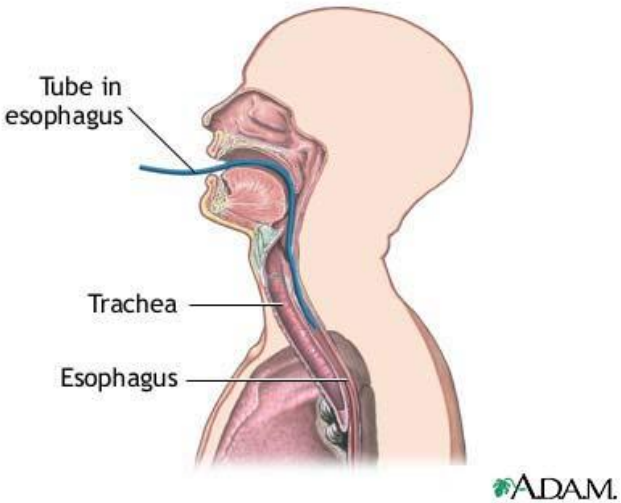


Patient effort causes poor estimations of respiratory mechanics

Underestimation of respiratory system elastance and overestimation of resistance

What can be done?

- Additional invasive monitoring to quantify the patient effort
- Inhibit the patients effort with sedatives and muscle relaxants



These options have some considerable drawbacks

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Our Approach – Pressure Reconstruction

- **P**ressure **R**econstruction by **E**liminating the **D**em**A**nd effec**T** of sp**O**ntaneous **R**espiration

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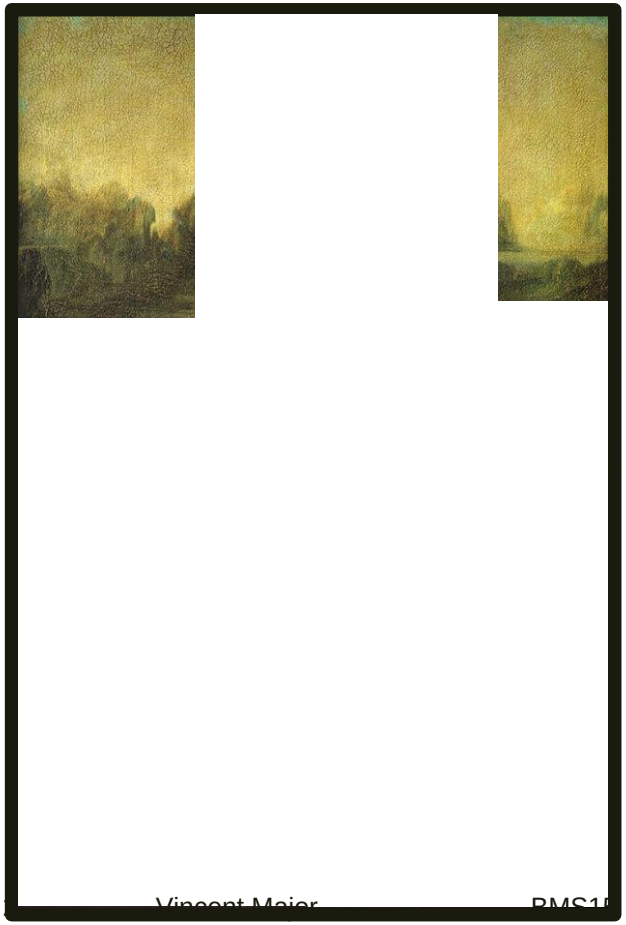

With sufficient information and data gathering, we can estimate what is the overall picture

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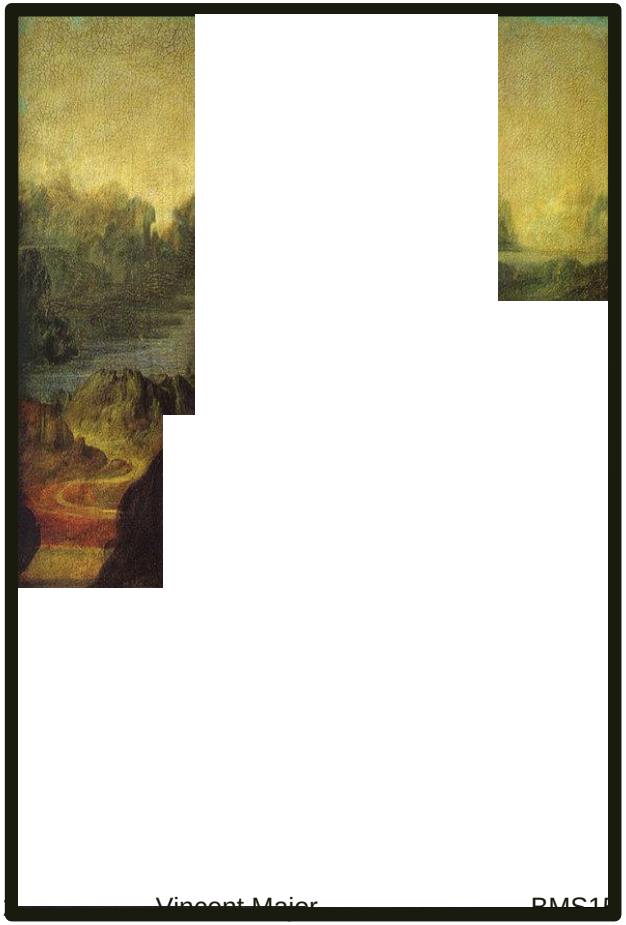

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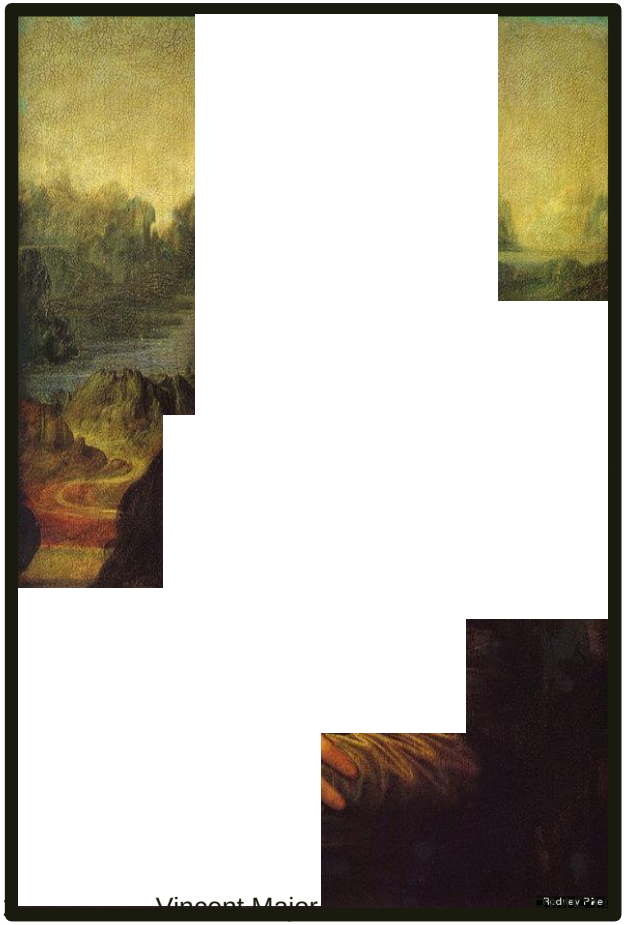

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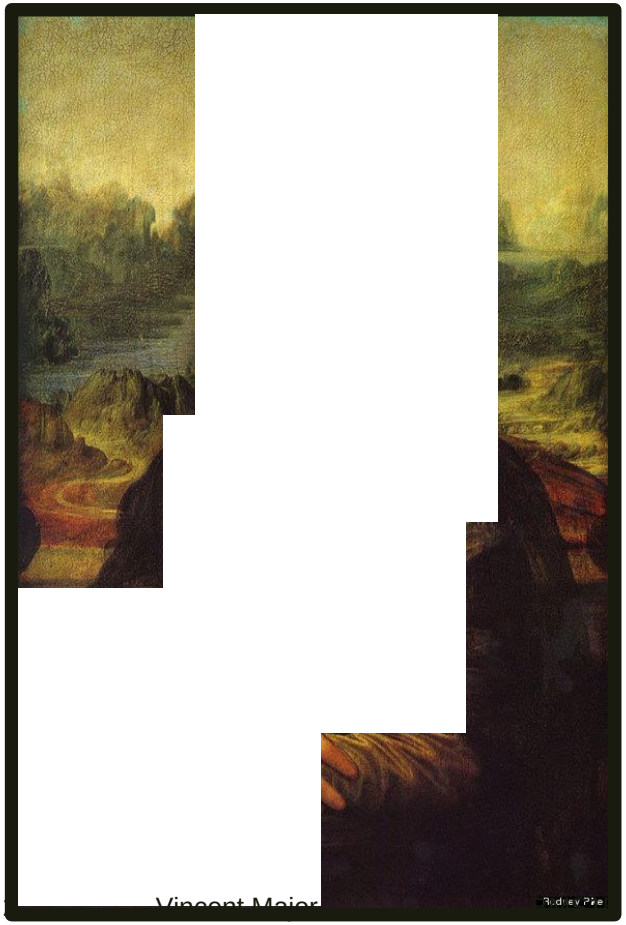

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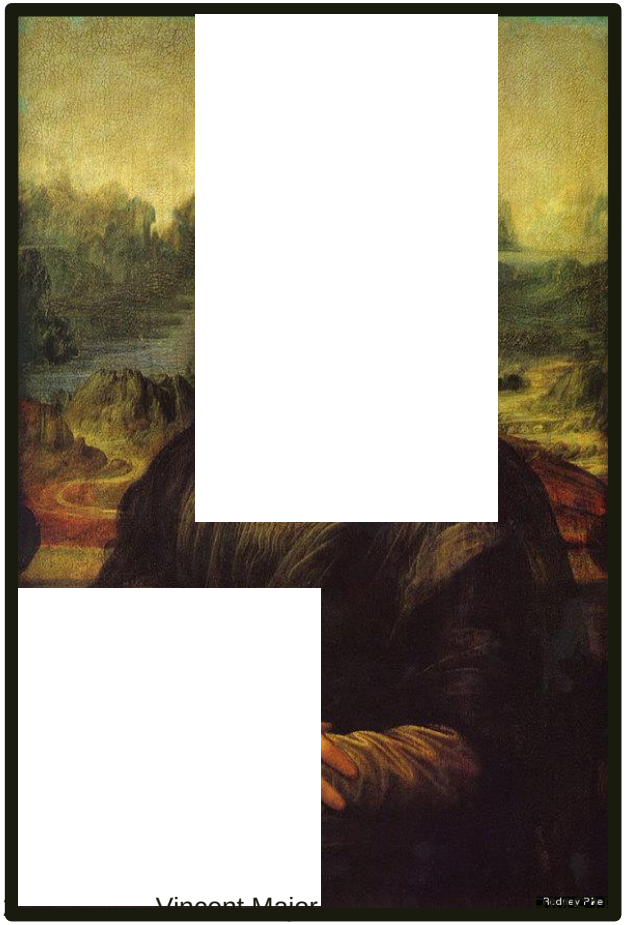

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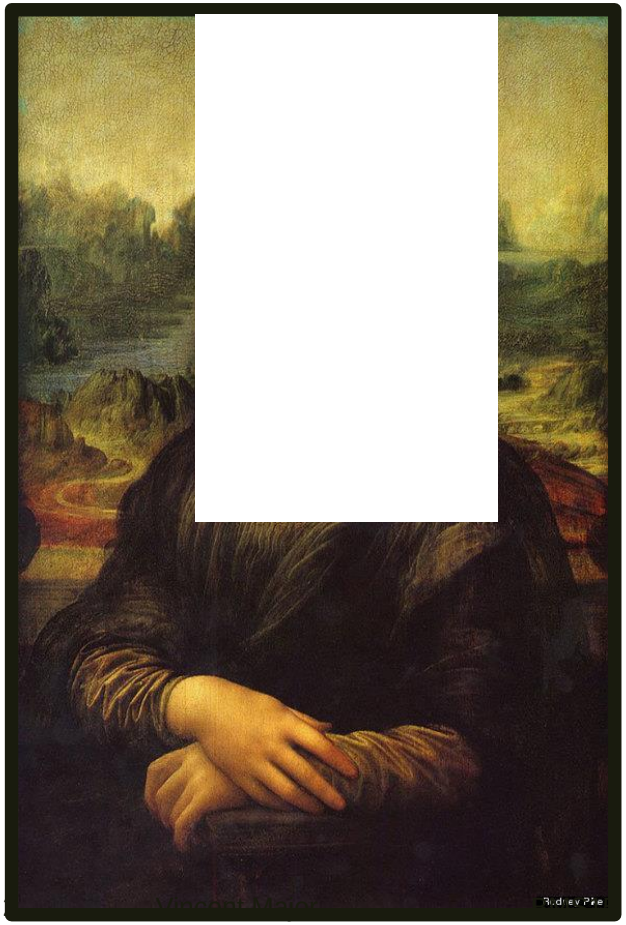

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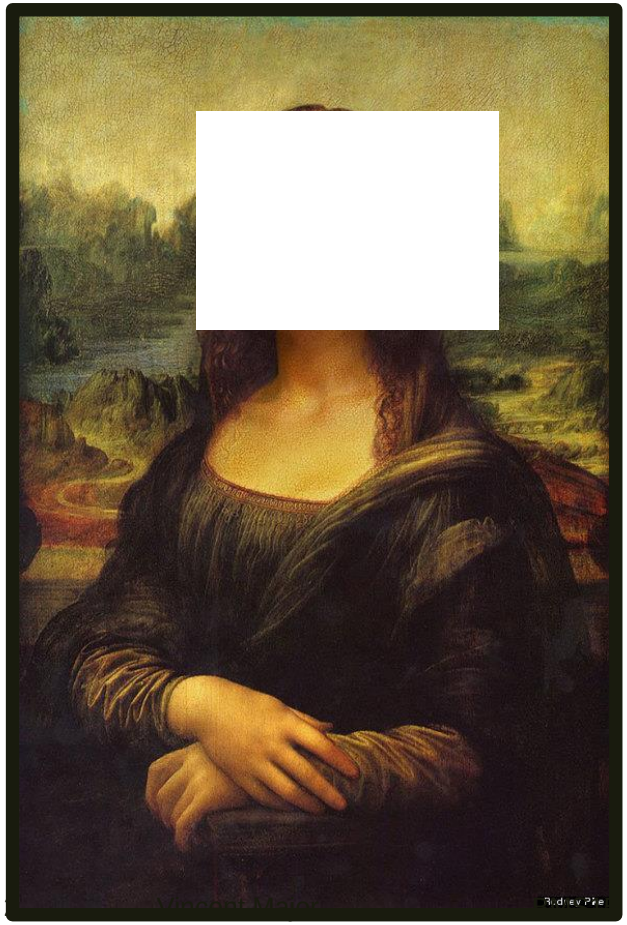
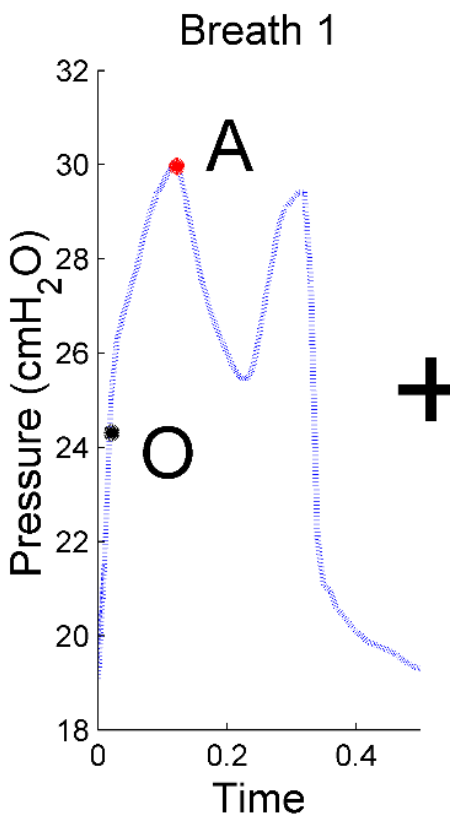


But, we might never get enough data!

Our Approach – Pressure Reconstruction



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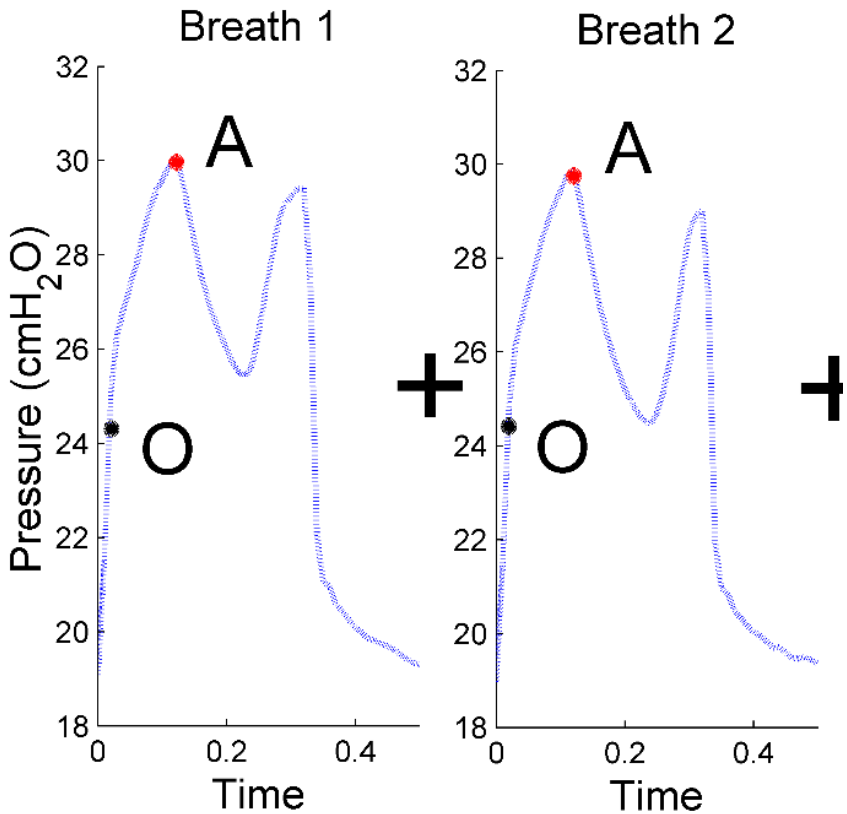

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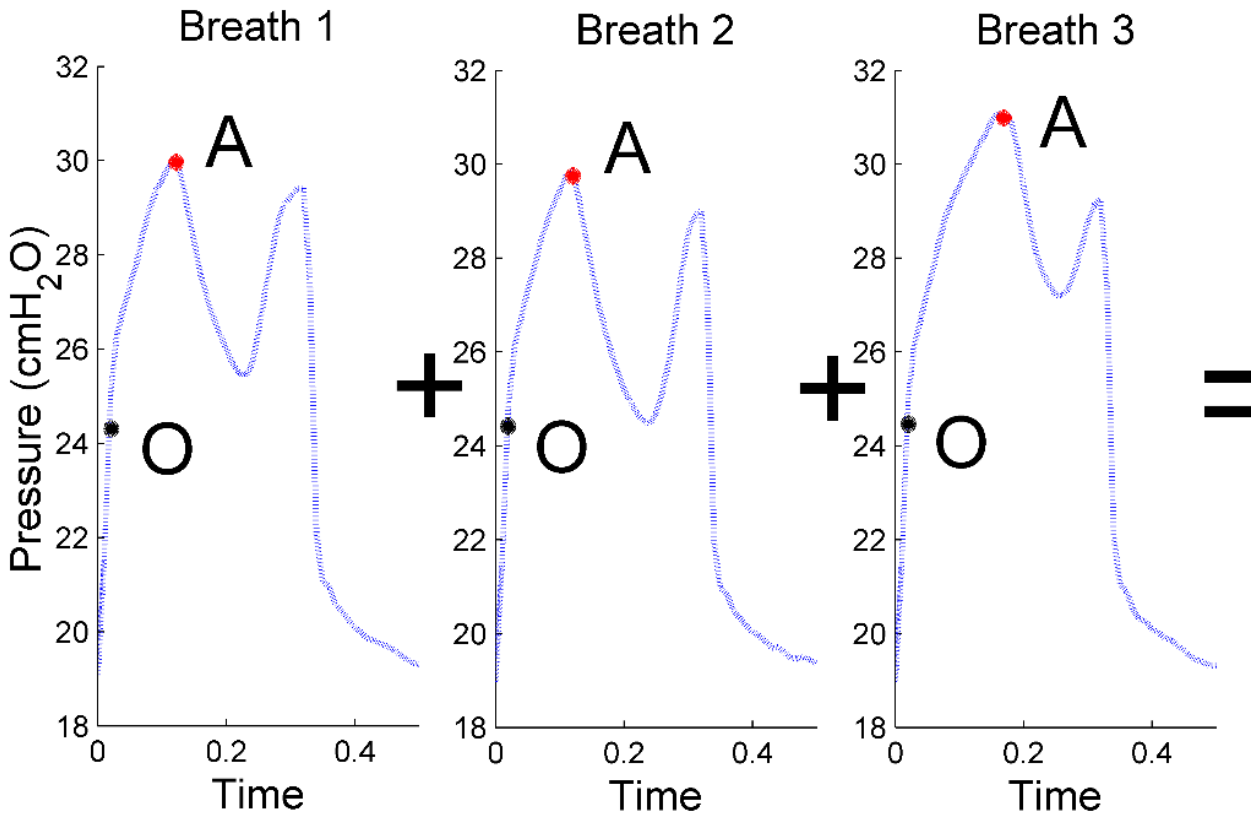

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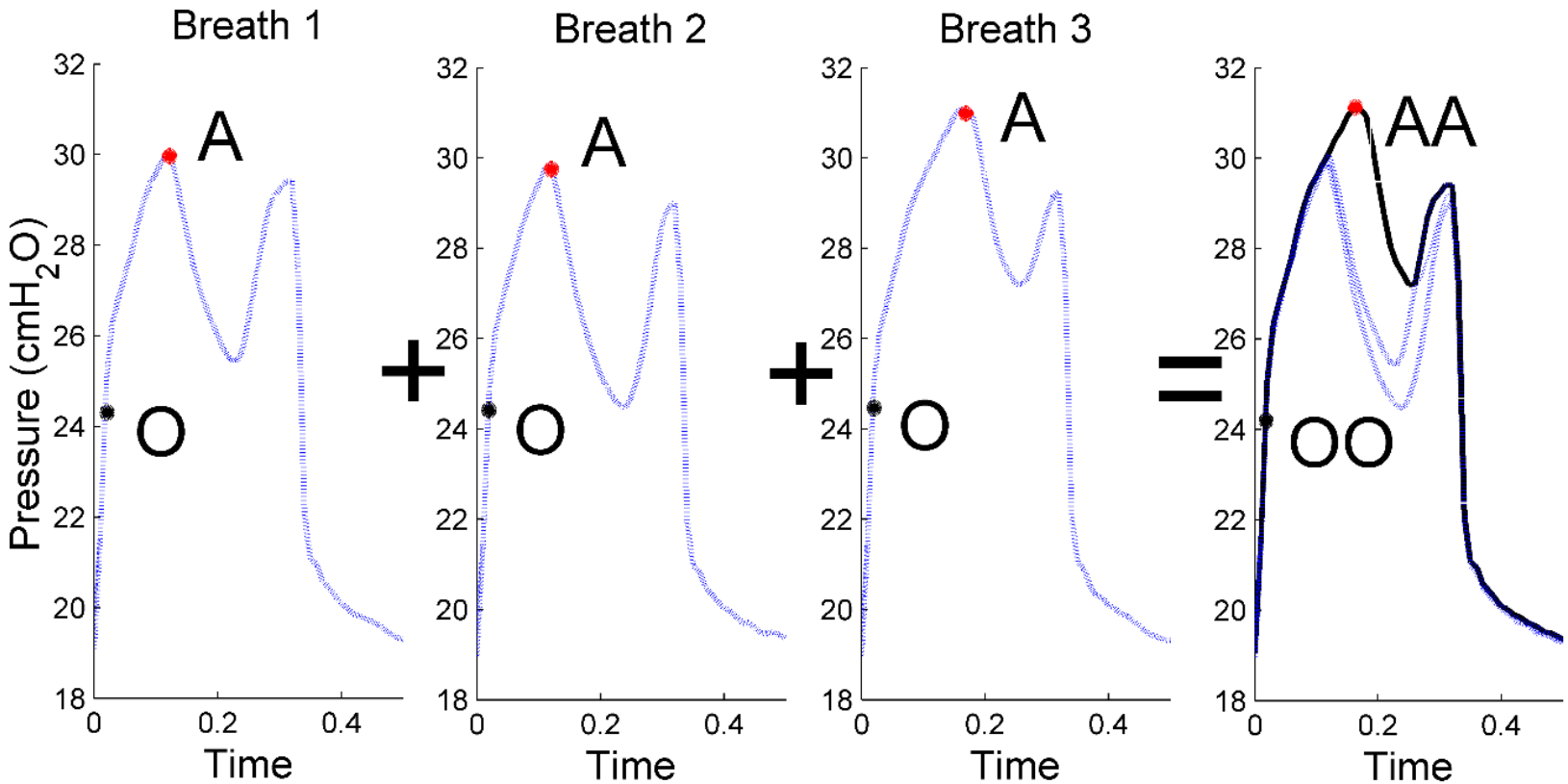
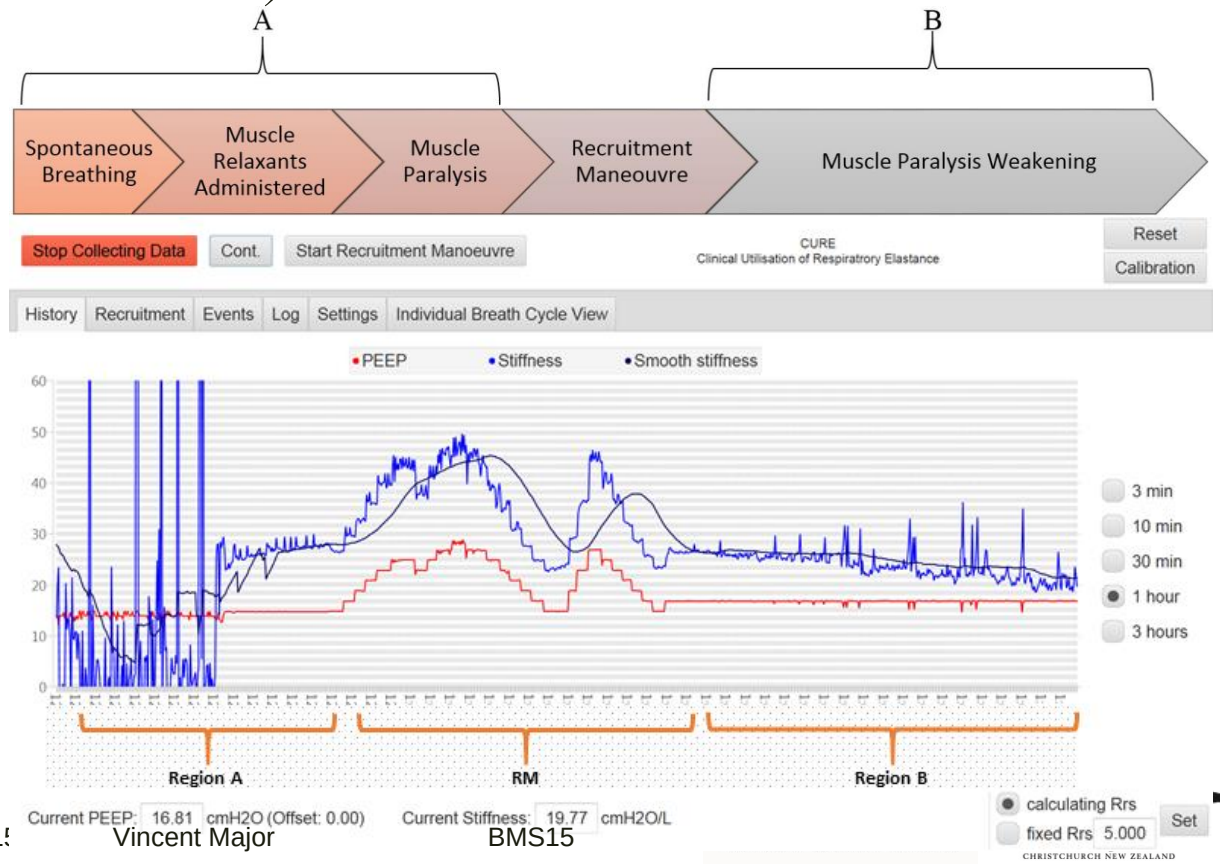


Clinical Data Set & Timeline

- **Comparing regions of spontaneous breathing with paralyzed regions.**
  - *A - Patient is paralyzed for clinical purposes (rapid change in condition).*
  - *B - Muscle relaxants are metabolised and cleared from the system (slow change in condition).*



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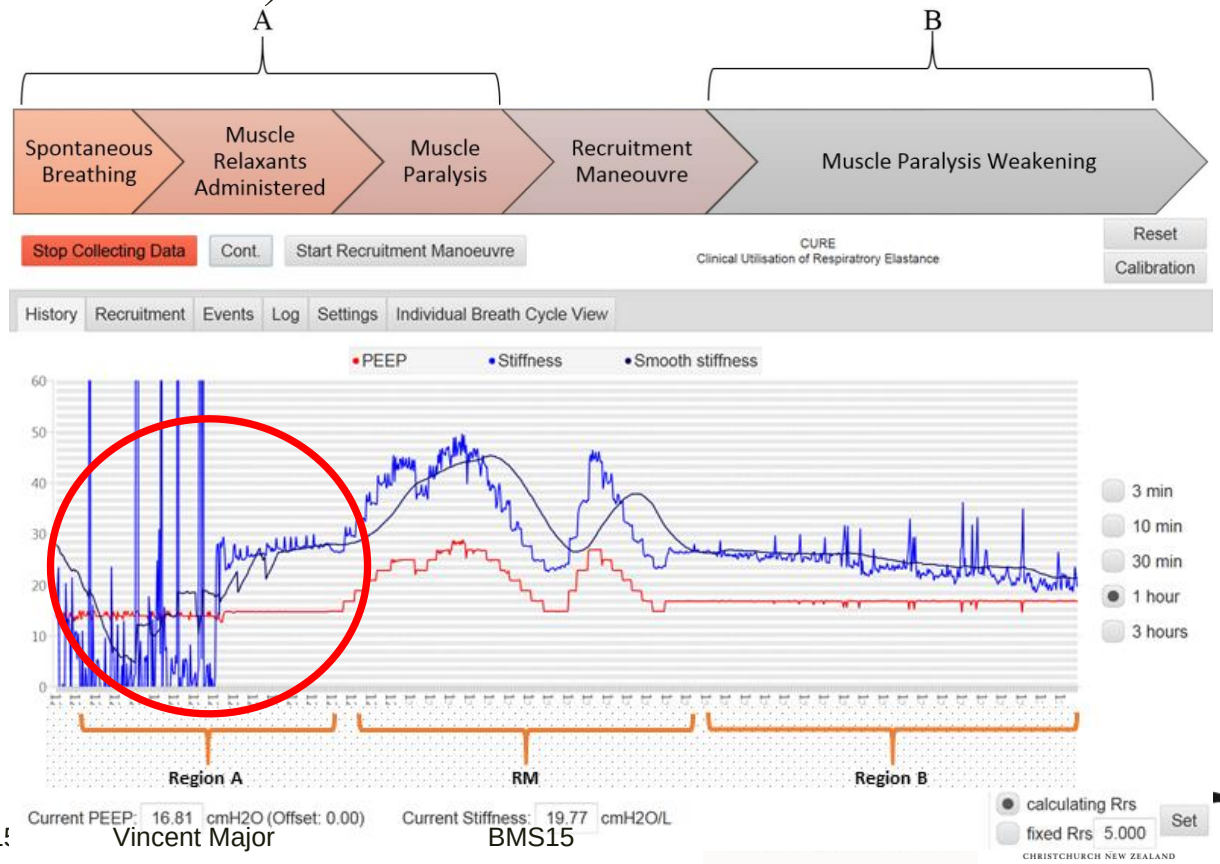
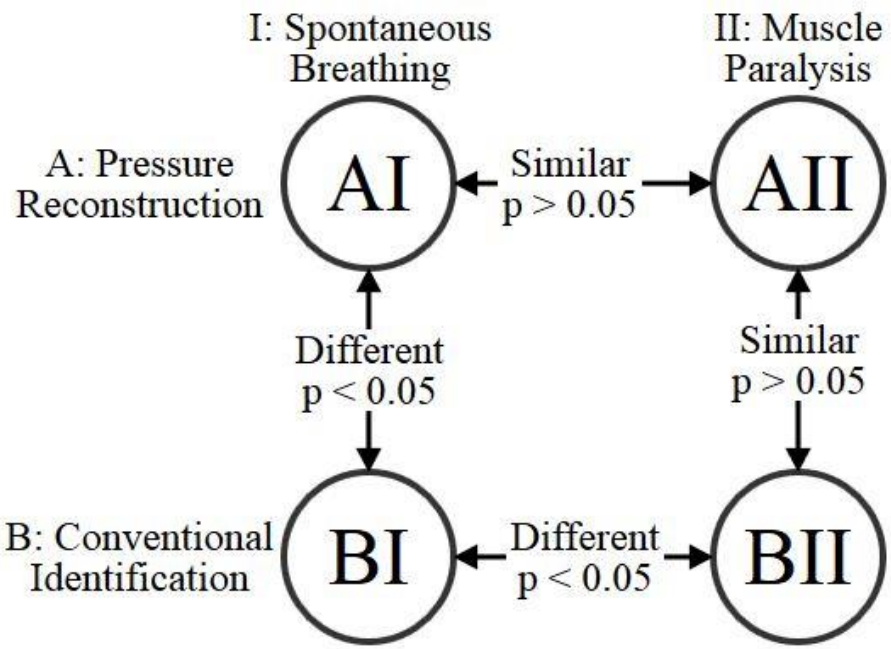
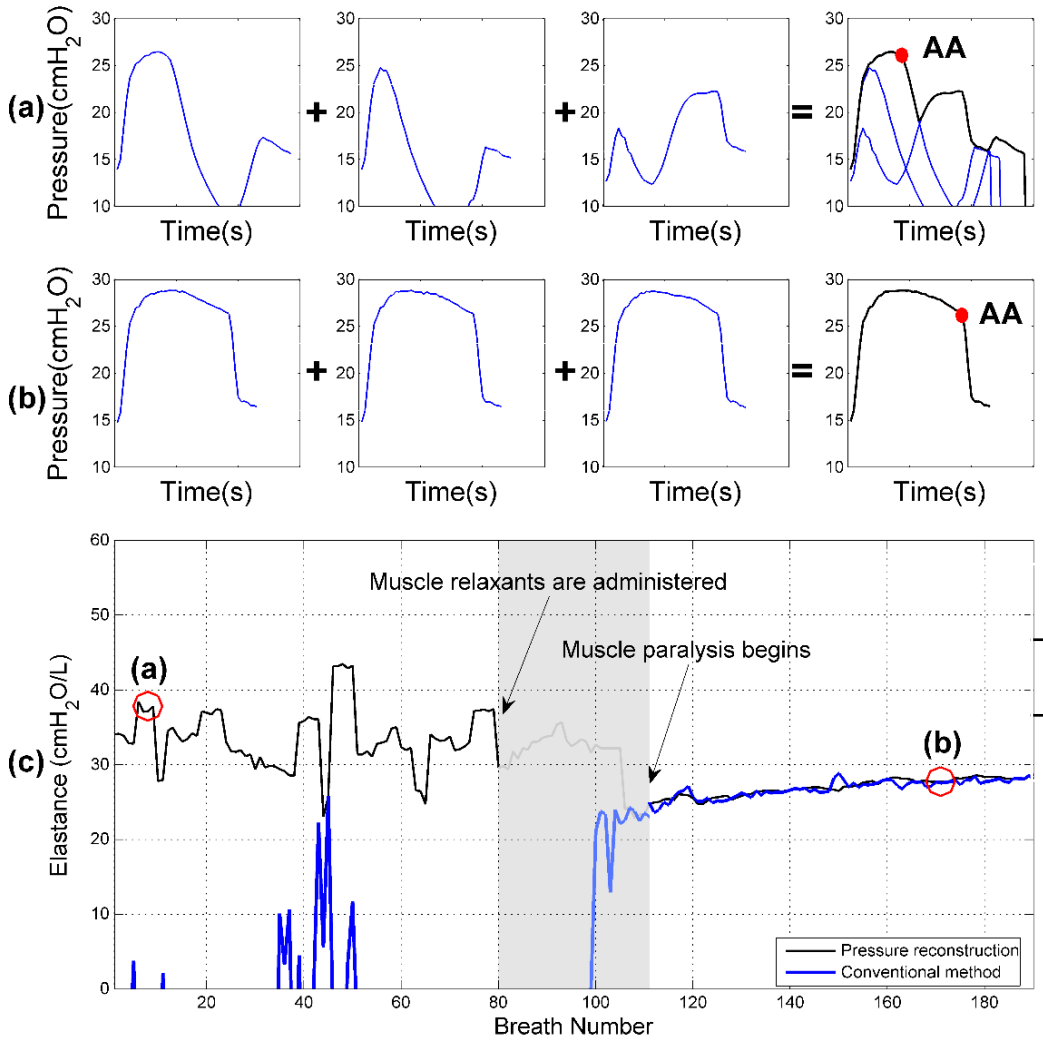


Clinical Data Set & Comparison of Four Cases

- **Comparing regions of spontaneous breathing with paralyzed regions both before and during paralysis.**
  - *Compare the respiratory elastance values in the four cases to check against the expected p-values.*

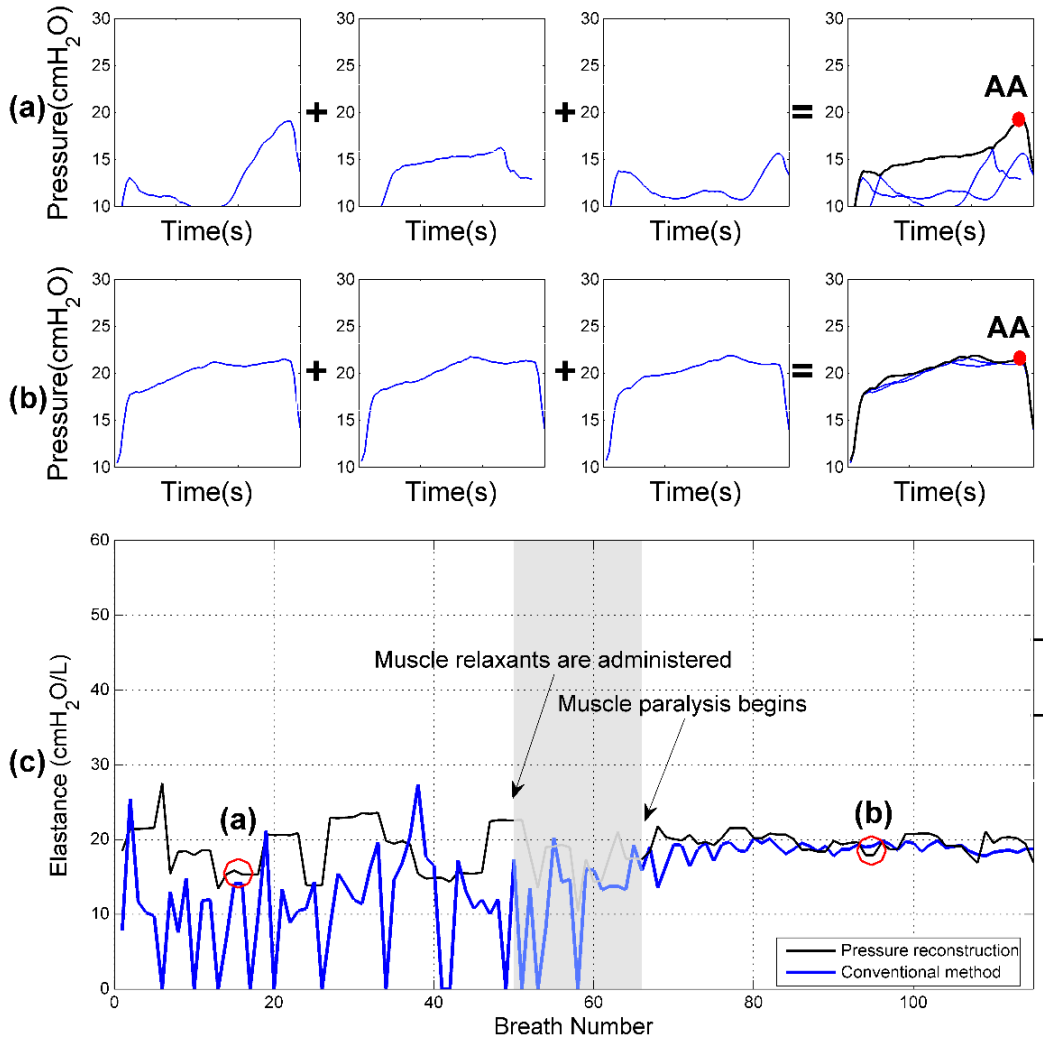


Patient 1 – Region A



AI	P < 0.05	AII
P < 0.05		P > 0.05
BI	P < 0.05	BII

Patient 2 – Region A



AI	P > 0.05	AII
P < 0.05		P < 0.05
BI	P < 0.05	BII

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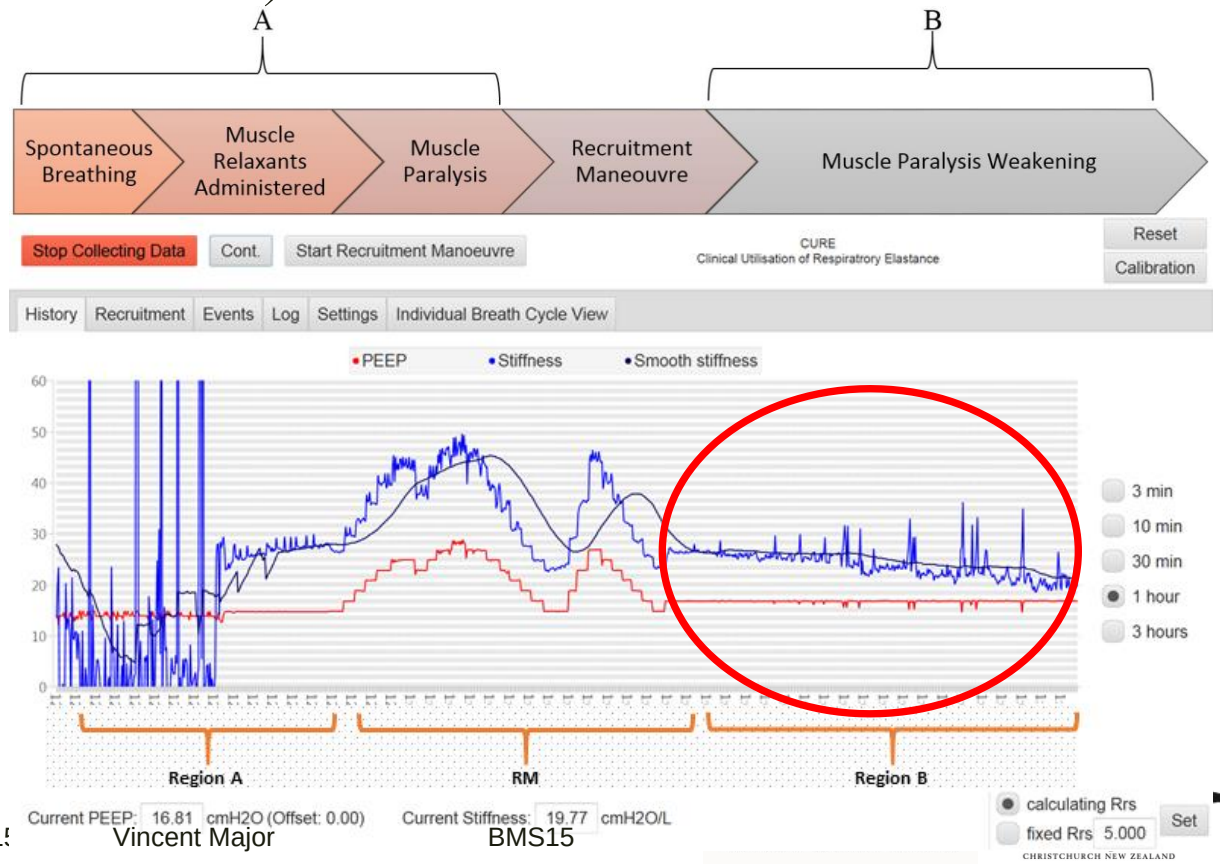
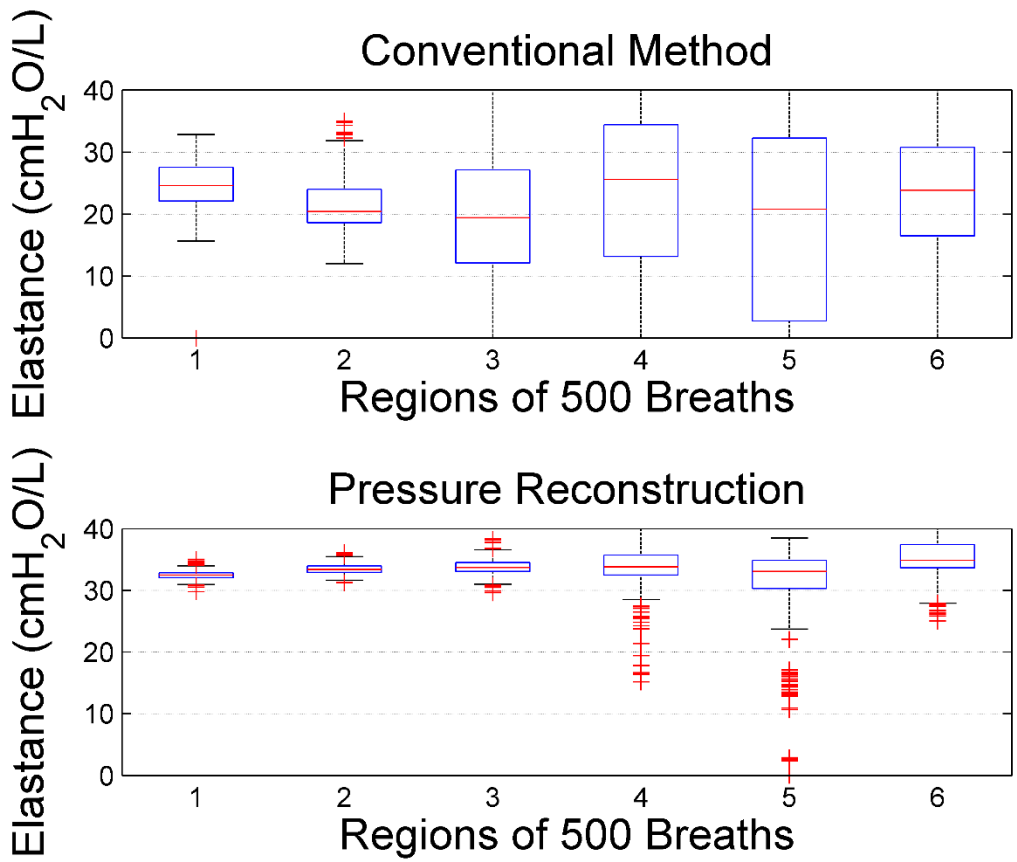


3 hours of data.
6 regions.

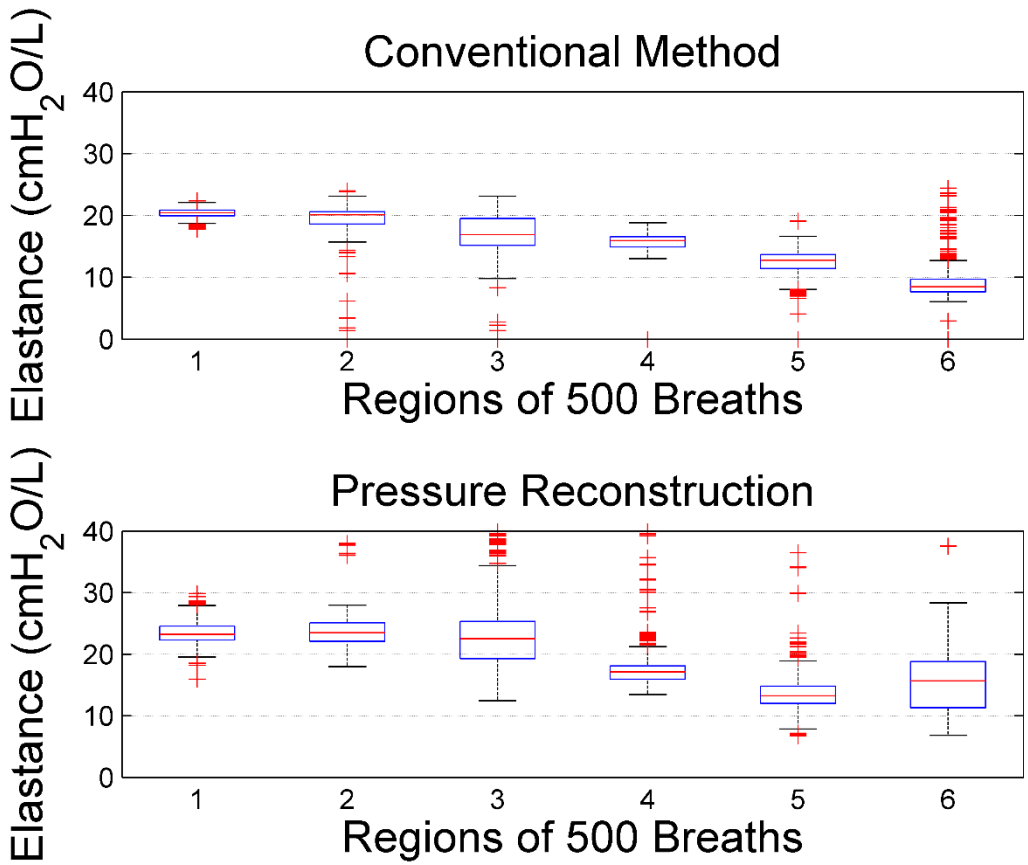
Patient 1 – Region B



Boxplots are *Diverging!*

$P < 0.05 \ \forall$ cases

Patient 2 – Region B



$P < 0.05 \ \forall$ cases

Limitations

- Pressure reconstruction only works on volume control ventilator modes, where the patient effort influences the pressure waveform.
- Pressure reconstruction is reliant on the patient's respiratory effort occurring at different times in each breath.
- If the patient efforts consistently occurs very early in the breath, there is not enough 'unaffected' data to make an estimate of respiratory mechanics.

Conclusions

- The pressure reconstruction method can be used for more stable (less variable) estimates of respiratory mechanics when patient efforts are occurring during ventilator controlled breaths.
- Improved estimates of respiratory mechanics eases the use of patient-specific MV therapy in a larger, less paralyzed, cohort.
- We can test minimal elastance PEEP in the ICU without paralyzing every patient.

Acknowledgement

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Thank you!