Time-Varying Respiratory Elastance for Spontaneously Breathing Patients

Yeong Shiong Chiew, Sarah F. Poole, Daniel P. Redmond, Erwin J. van Drunen, Nor Salwa Damanhuri, Christopher Pretty, Paul D. Docherty, Bernard Lambermont, Geoffrey M. Shaw, Thomas Desaive, J. Geoffrey Chase

Department of Mechanical Engineering, University of Canterbury, Christchurch, New Zealand

GIGA-Cardiovascular Sciences, Thermodynamics of Irreversible Processes, University of Liege, Liege, Belgium

Intensive Care Unit, Christchurch Hospital, Christchurch, New Zealand

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  - *Respiratory Failure and Mechanical Ventilation*
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- *Respiratory Mechanics*
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- *Conclusion*

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- Patients with impaired lung functions, collapse lung, resulting in poor gas exchange

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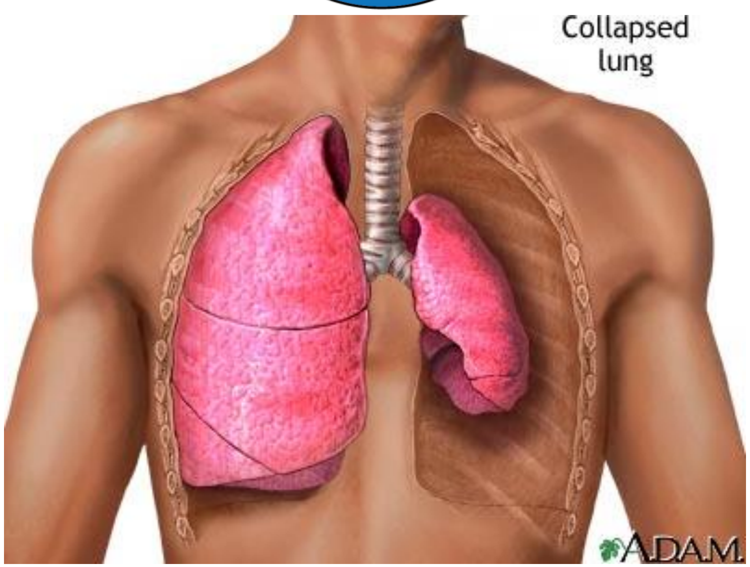

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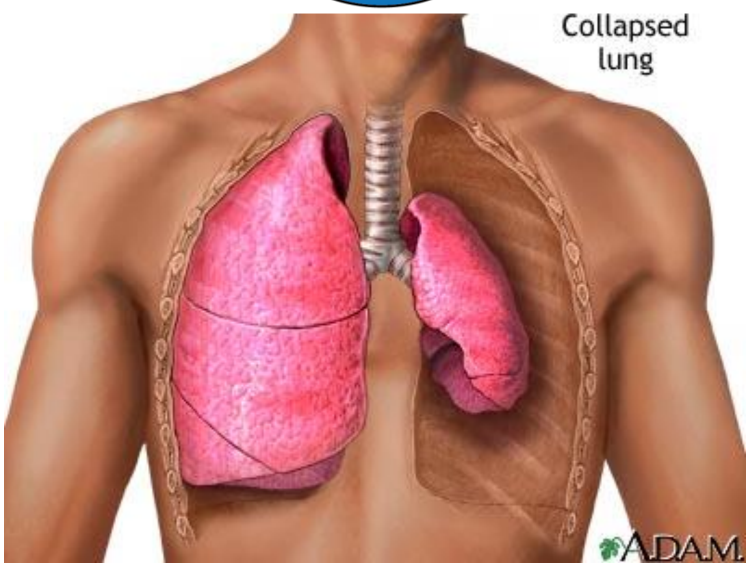

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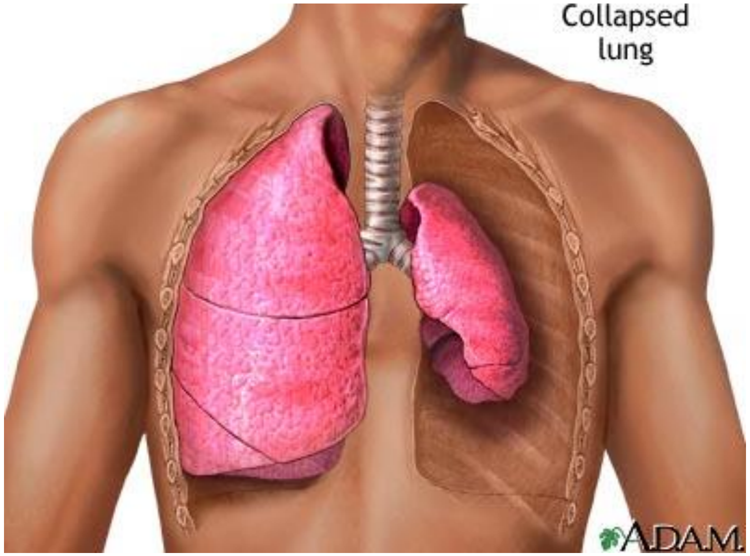

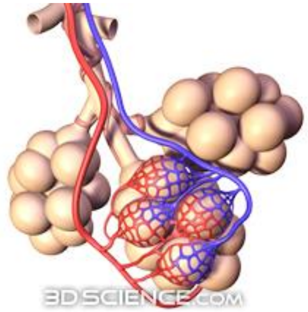

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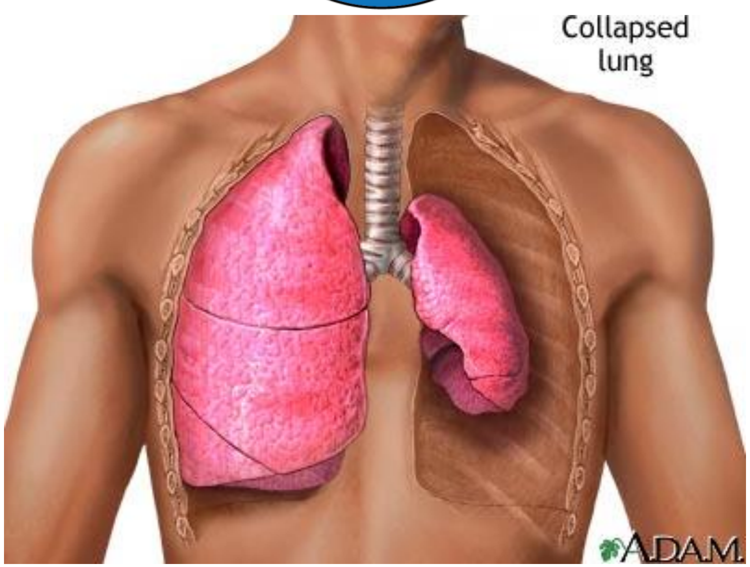

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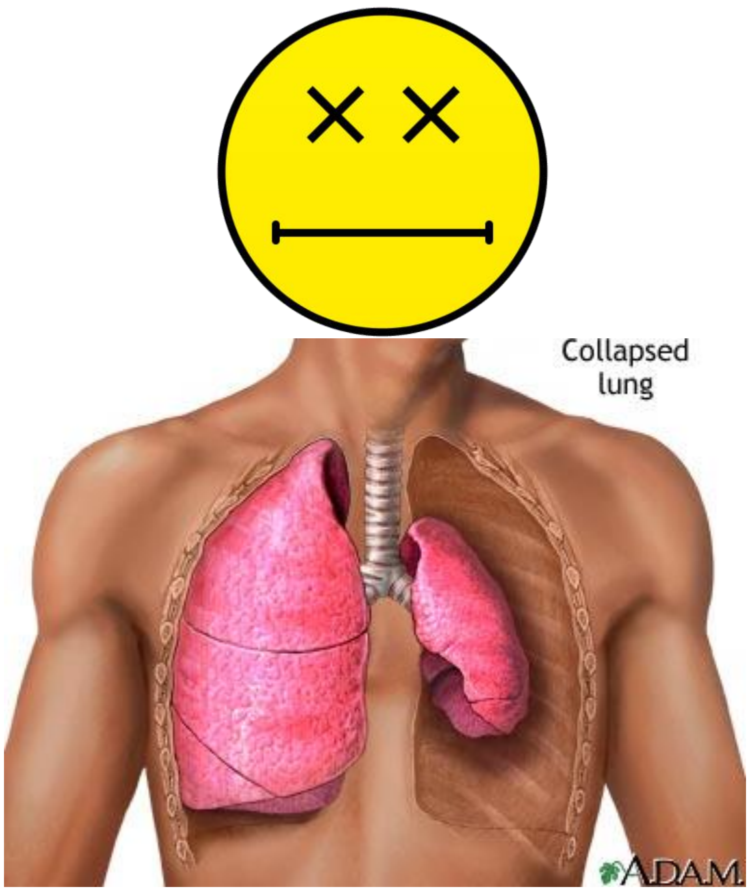

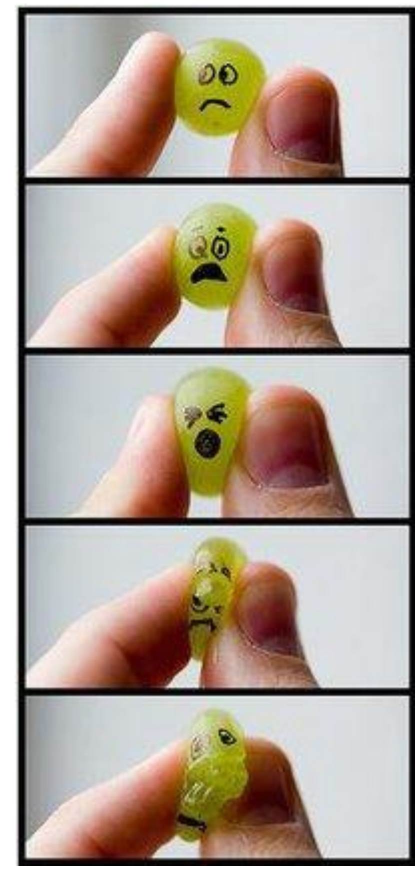

Respiratory Failure and Mechanical Ventilation

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- Pneumonia, Trauma, Sepsis, Drowning, Drug overdose, aspiration…etc

Respiratory Failure and Mechanical Ventilation

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- Mechanical Ventilation (MV) is the primary support for patients with respiratory failure.
  - Provide a pressure/ air volume
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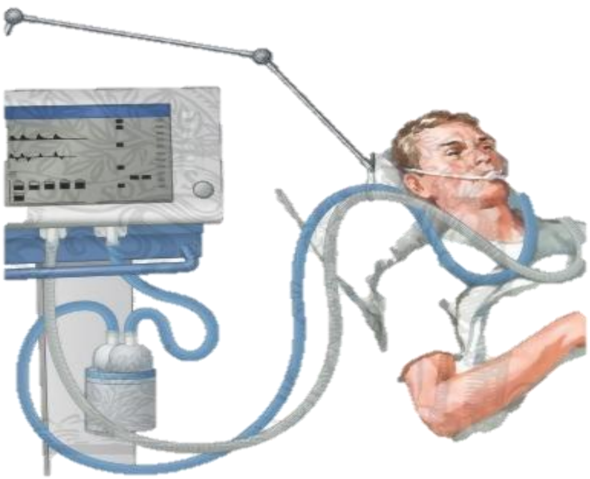

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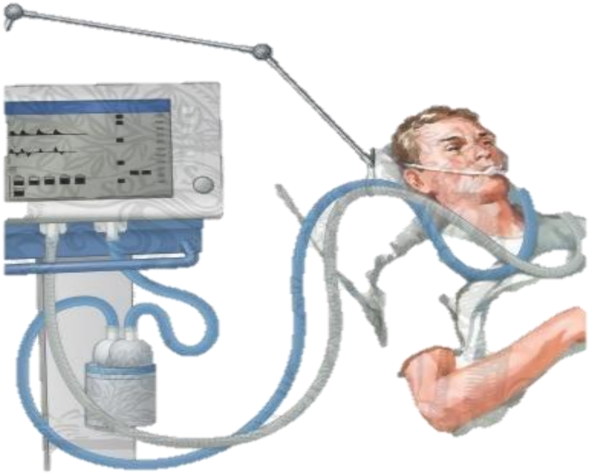
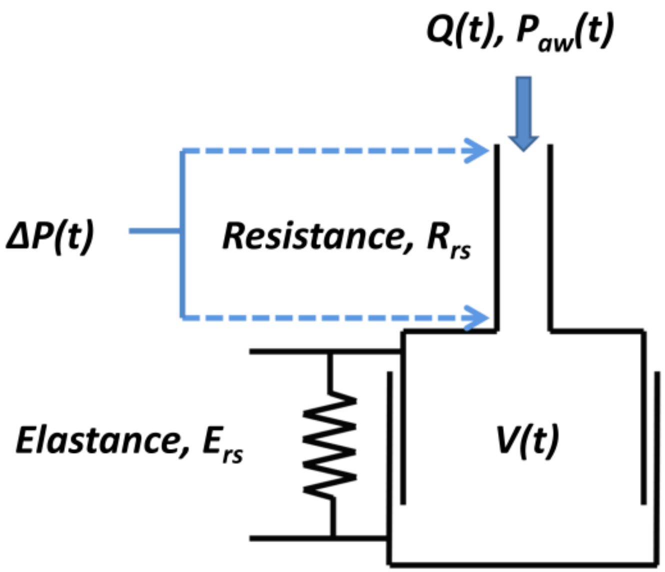
- Respiratory mechanics to guide MV therapy



Conventional Single Compartment Lung Model

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

P_{aw}	- Airway pressure
t	- Time
R_{rs}	- **Airway resistance**
Q	- Air flow
E_{rs}	- **Respiratory System Elastance**
V	- Lung volume
P_o	- Offset pressure



- Lung elastance (E_{rs}) is an **indicator** for recruitment and overdistension
- **PEEP can be set at minimal Elastance to maximise recruitment while minimising the risk of overdistension**
- **Monitoring Elastance continuously provides information the on patients disease state progression**

Reference

Suarez-Sipmann F et al., *Crit Care Med* 2007, **35:**214 - 221.
Carvalho A et al., *Critical Care* 2007, **11:**R86.
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Chiew YS et al., *BioMedical Engineering OnLine* 2011, **10:**111.
Pintado M-C et6 al., *Respiratory Care* 2013, **58:**1416-1423.

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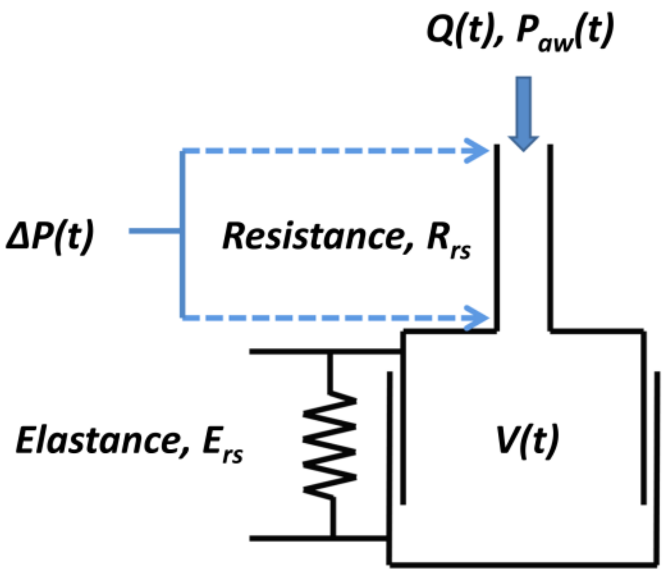
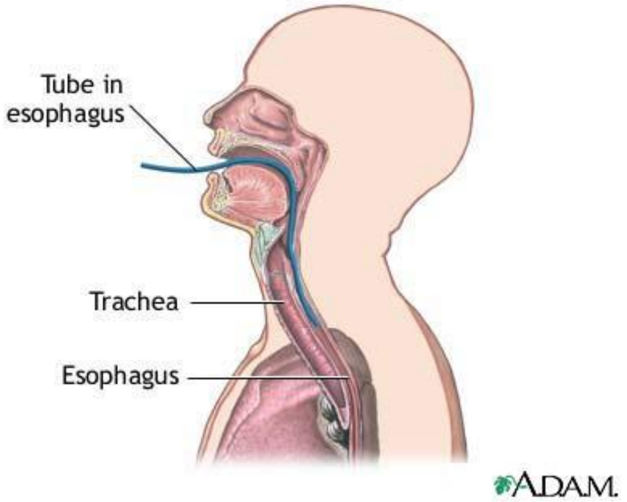


What if... patient is spontaneously breathing? Can we still use the single compartment lung model?

- Yes... but we need more equipment
- To measure oesophageal pressure using a balloon catheter

- $P_{aw}(t) - P_{pl}(t) = R_{rs} * Q(t) + E_{rs} * V(t) + P_o$

P_{pl} - Pleural Pressure or measured as Oesophageal pressure



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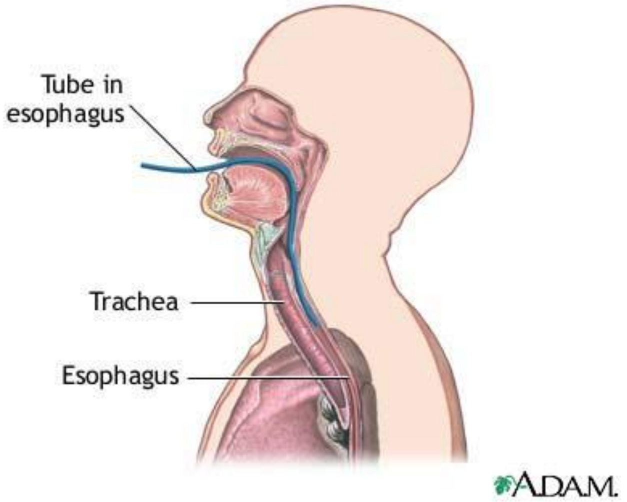

- **But…**
  - **Invasive**
  - **Approximation**
  - **Dependent of location of the measurement**

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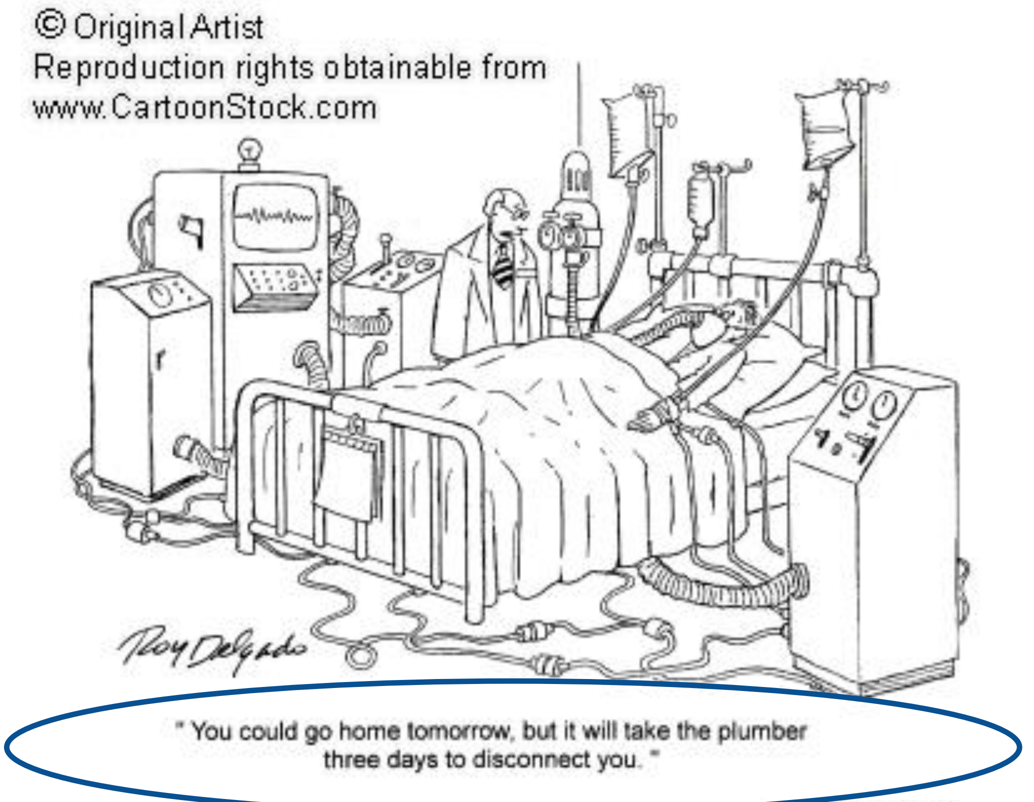
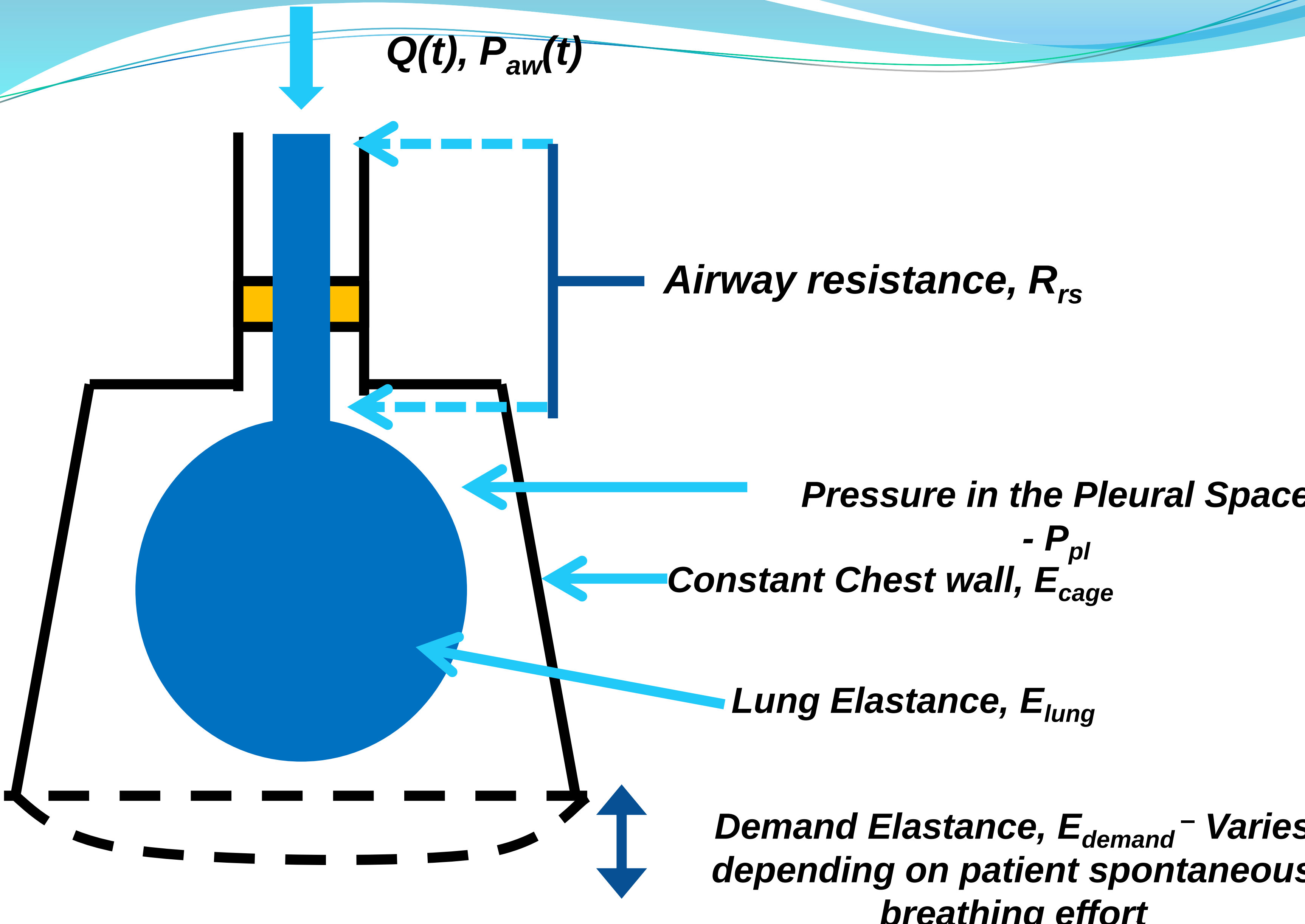
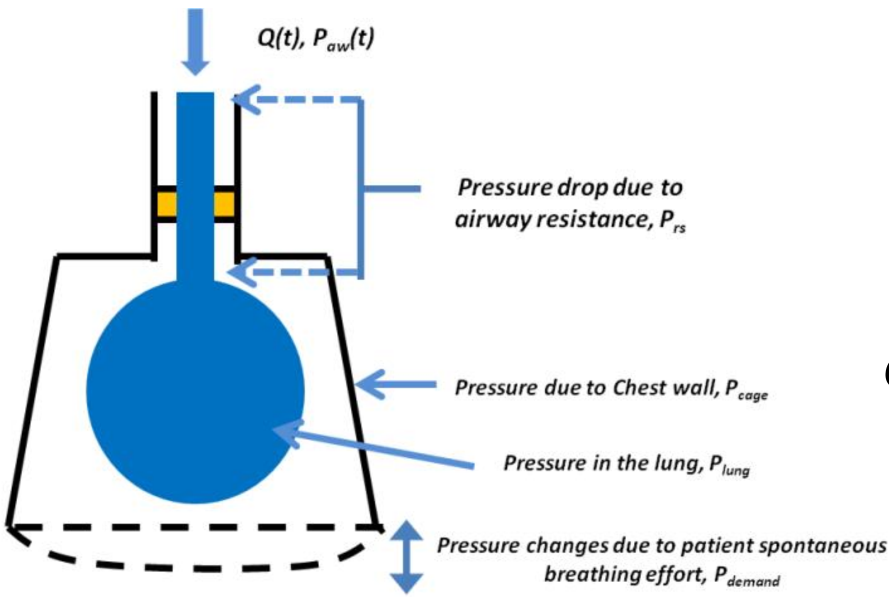


- But…
  - Invasive
  - Approximation
  - Dependent of location of the measurement
- We need an alternative



Q(t), P_aw(t)
Airway resistance, R_rs
Pressure in the Pleural Space - P_pl
Constant Chest wall, E_cage
Lung Elastance, E_lung
Demand Elastance, E_demand – Varies depending on patient spontaneous breathing effort

A Time-Varying Elastance Model



Constant Chest wall, E_{cage}

Lung Elastance, E_{lung}

Demand Elastance, E_{demand} – Varies depending on patient spontaneous breathing effort

- $P_{aw}(t)=R_{rs}\times Q(t)+E_{rs}\times V(t)$ (1)
- $E_{drs}(t)=E_{cage}(t)+E_{demand}(t)+E_{lung}(t)$ (2)
- $P_{aw}(t)=(E_{cage}(t)+E_{demand}(t)+E_{lung}(t))\times V(t)+R_{rs}\times Q(t)$ (3)

A time-varying elastance model

Elung

- A time-varying measure of the elastic properties of the lung or the collection of alveoli.
- Elung decreases if overall alveoli recruitment outweighs the pressure build-up. Elung will increase if the overall alveoli are stretched with lesser or no further recruitment.

Echest

- The elastic properties of the chest wall, including the rib cage, and the intercostal muscles.
- This elastance subcomponent can be assumed not to vary with disease-state and is thus a patient-specific

Edemand

- Patient-specific inspiratory demand, which varies depending on patient-specific and breath-specific effort.
- The value of Edemand can be negative (Edemand < 0), as it represents the reduced apparent elastance due to the patient's inspiratory effort creating a pressure reduction in the pleural space to allow negative pressure ventilation.
- The negative Edemand proposed in this study is a construct, to capture this negative pressure changes that contribute the increasing lung volume.

Clinical Trials to test out the Extended Model

- Patients who are partially ventilated.
  - Using Pressure Support mode
  - Using Neurally Adjusted Ventilatory Assist mode

More Clinical Trials to test out the Extended Model

- Patients who are partially ventilated.
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Messerli FH: **Chocolate Consumption, Cognitive Function, and Nobel Laureates.** *New England Journal of Medicine*, **0:**null.

More Clinical Trials to test out the 'Extended' Model

- Patients who are partially ventilated.
  - Using Pressure Support mode
  - Using Neurally Adjusted Ventilatory Assist mode

- 22 patients in University Hospital of Geneva (Switzerland), Cliniques Universitaires St-Luc (Belgium)
- $E_{drs}(t)=E_{cage}(t)+E_{demand}(t)+E_{lung}(t)$

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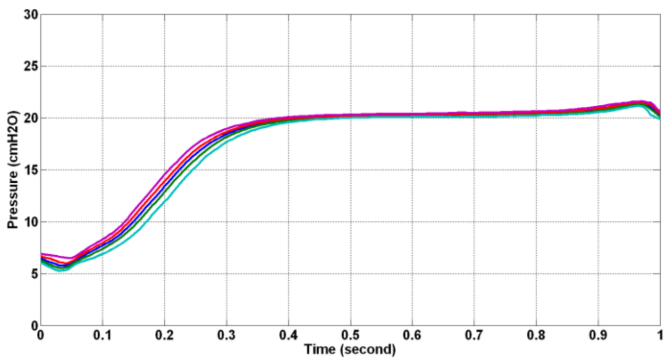
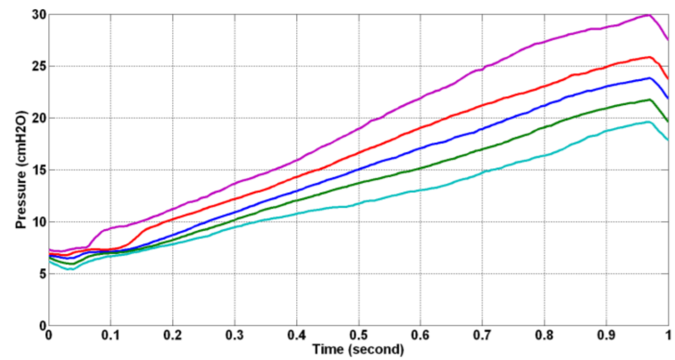
Airway Pressure, Volume during Inspiration

	Pressure Support	NAVA

Paw





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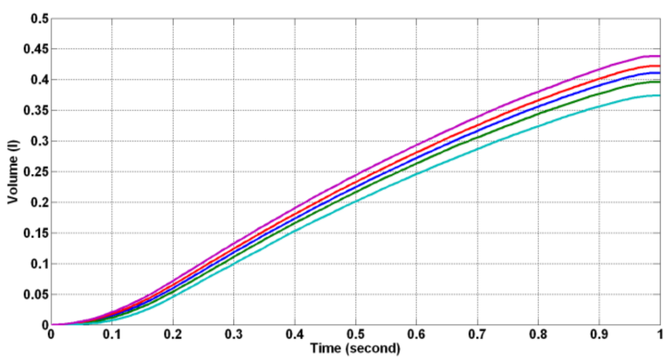

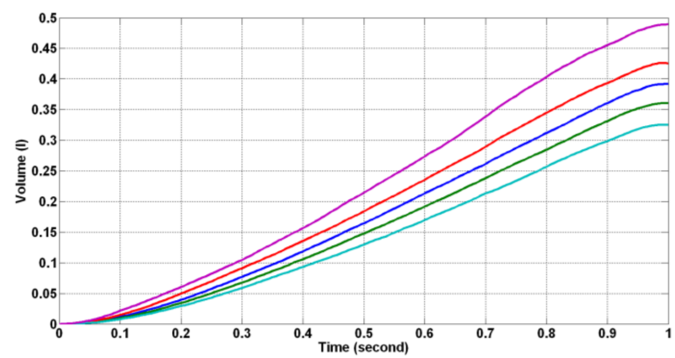

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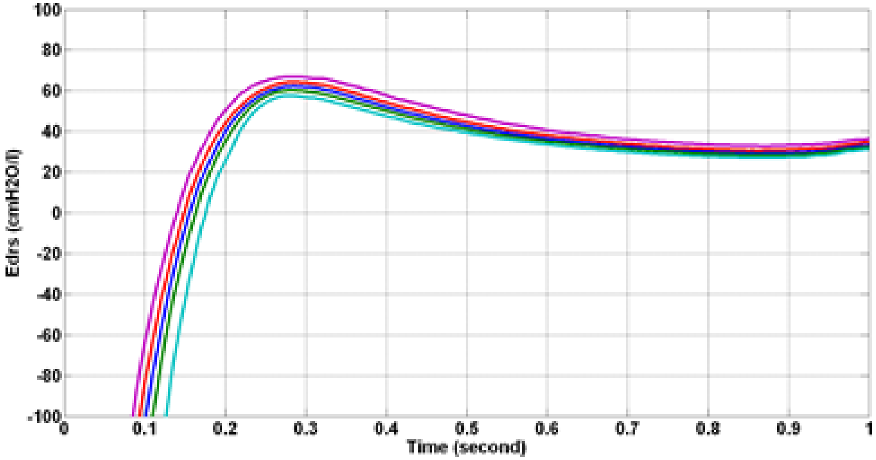
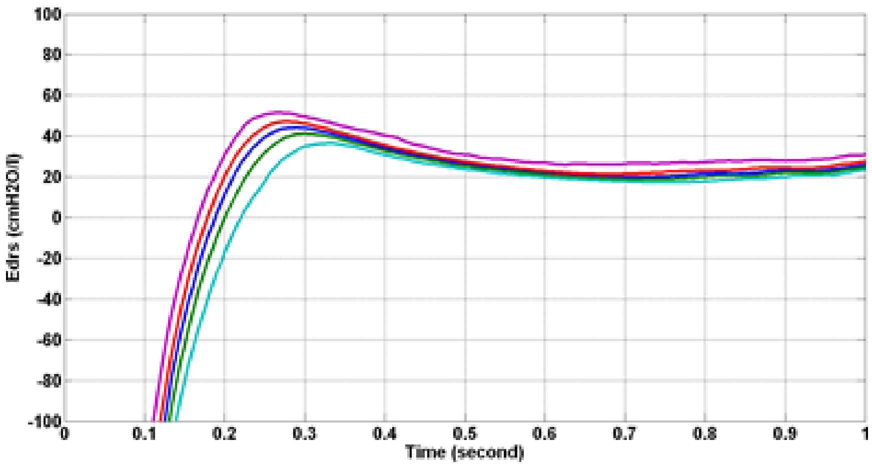
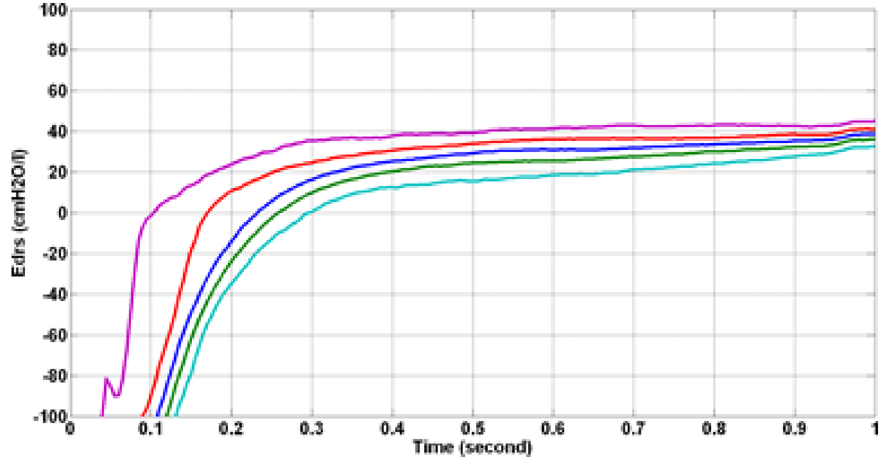
Edrs Trend during Partially Assisted Ventilation

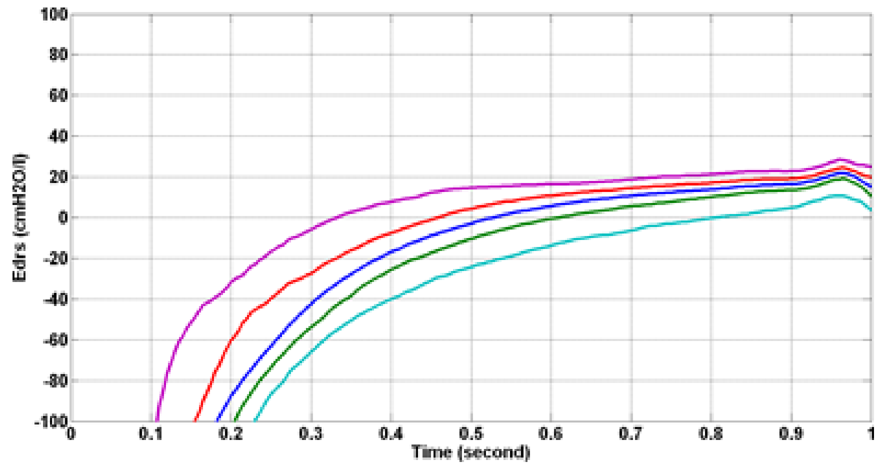
Pressure Support





Neurally Adjusted Ventilatory Assist





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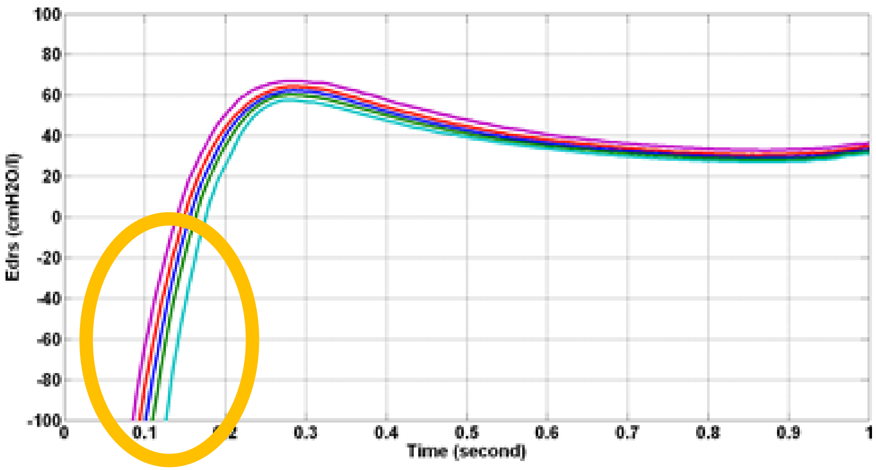

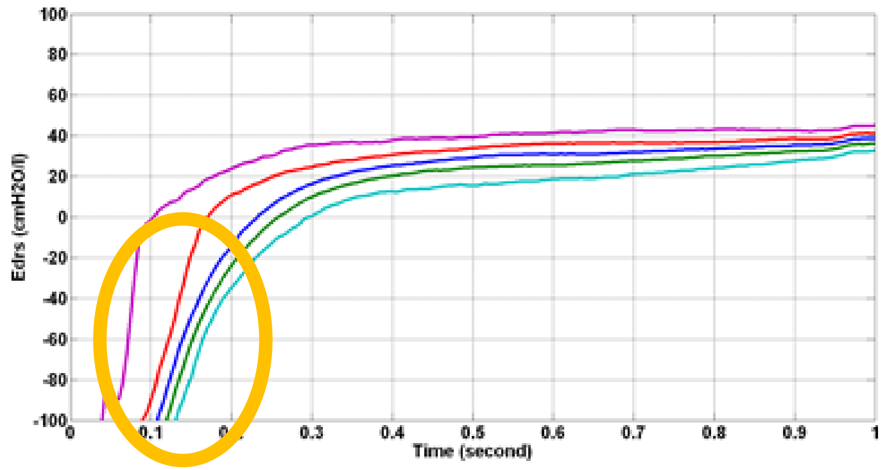

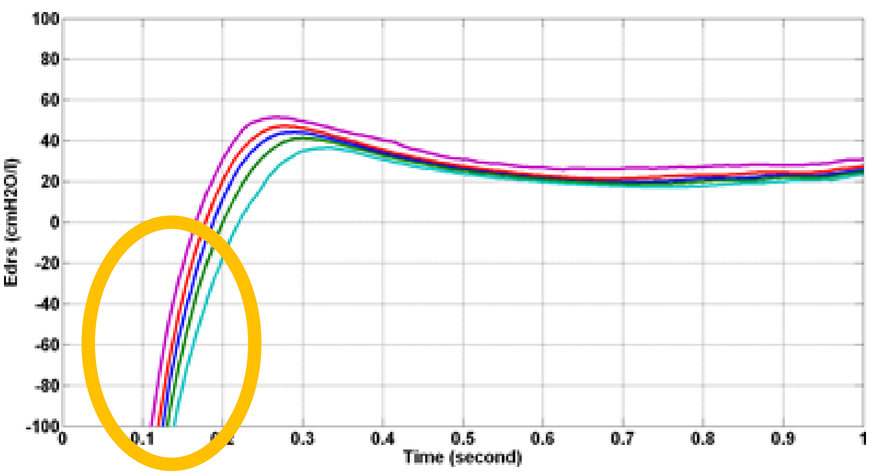

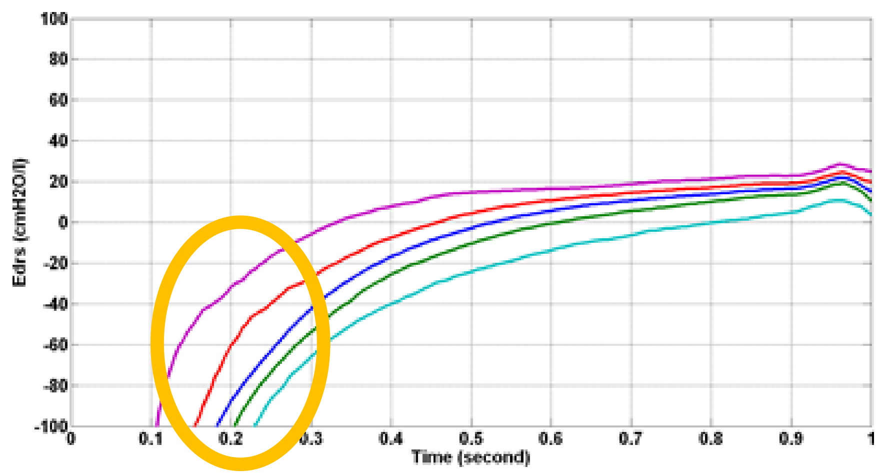

General Observation

- $E_{drs}(t) = E_{cage}(t) + E_{demand}(t) + E_{lung}(t)$
- E_{drs} begins as a negative value, again due to the negative pressure created in the pleural space due to patient inspiratory demand
- E_{drs} was typically wider in NAVA than in PS, occurring in 18 out of 22 patients ($p < 0.05$)
- $E_{drs} > 0$ implies that the positive pressure ventilation contributes or adds to the patient-specific lung elastance. Therefore, $E_{drs} > 0$ is a measure of patient lung condition and response to MV

On-going Study
Clinical Utilisation of Respiratory Elastance Trial (CURE)

<table>
<tr><th></th><th></th><th>Spontaneous breathing</th><th>Paralysed</th><th>Regaining Spontaneous breathing</th></tr>
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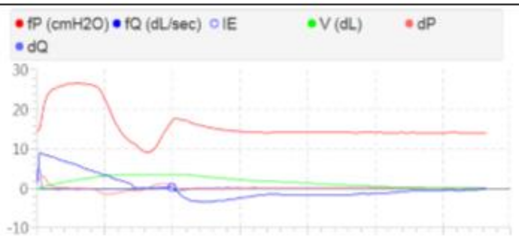
<td>
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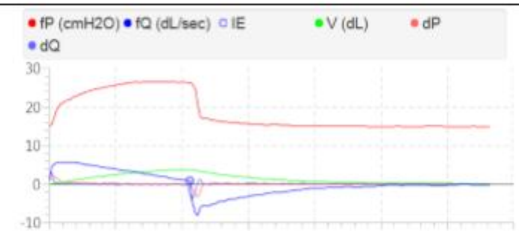
<td>
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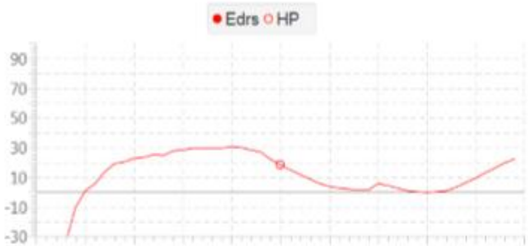
<tr><td>E_{drs}</td>
<td>
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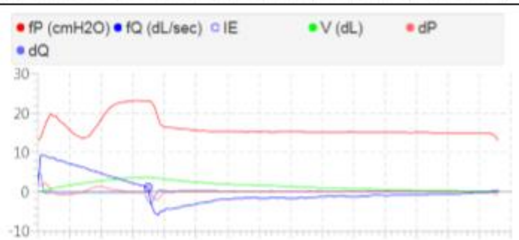
<td>
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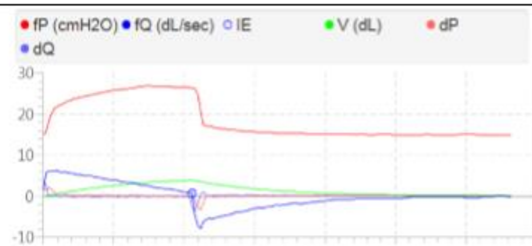
<td>
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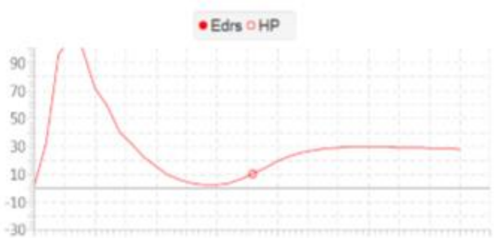
<td>
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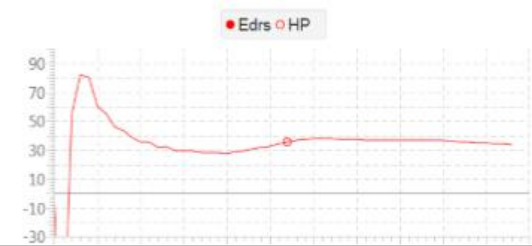
<td>
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Conclusions

- An extended model that defines conventional respiratory elastance into 3 separate components is presented.
- The proposed model was able to capture unique dynamic respiratory mechanics for spontaneously breathing patients during PS and NAVA, which is otherwise not possible without added invasive manoeuvres that interrupt conventional care methods.
- It is a fully general model that is applicable to all MV modes and conditions with the resulting potential to 'standardise' treatment for all sedated and non-sedated MV patients.

Acknowledgement

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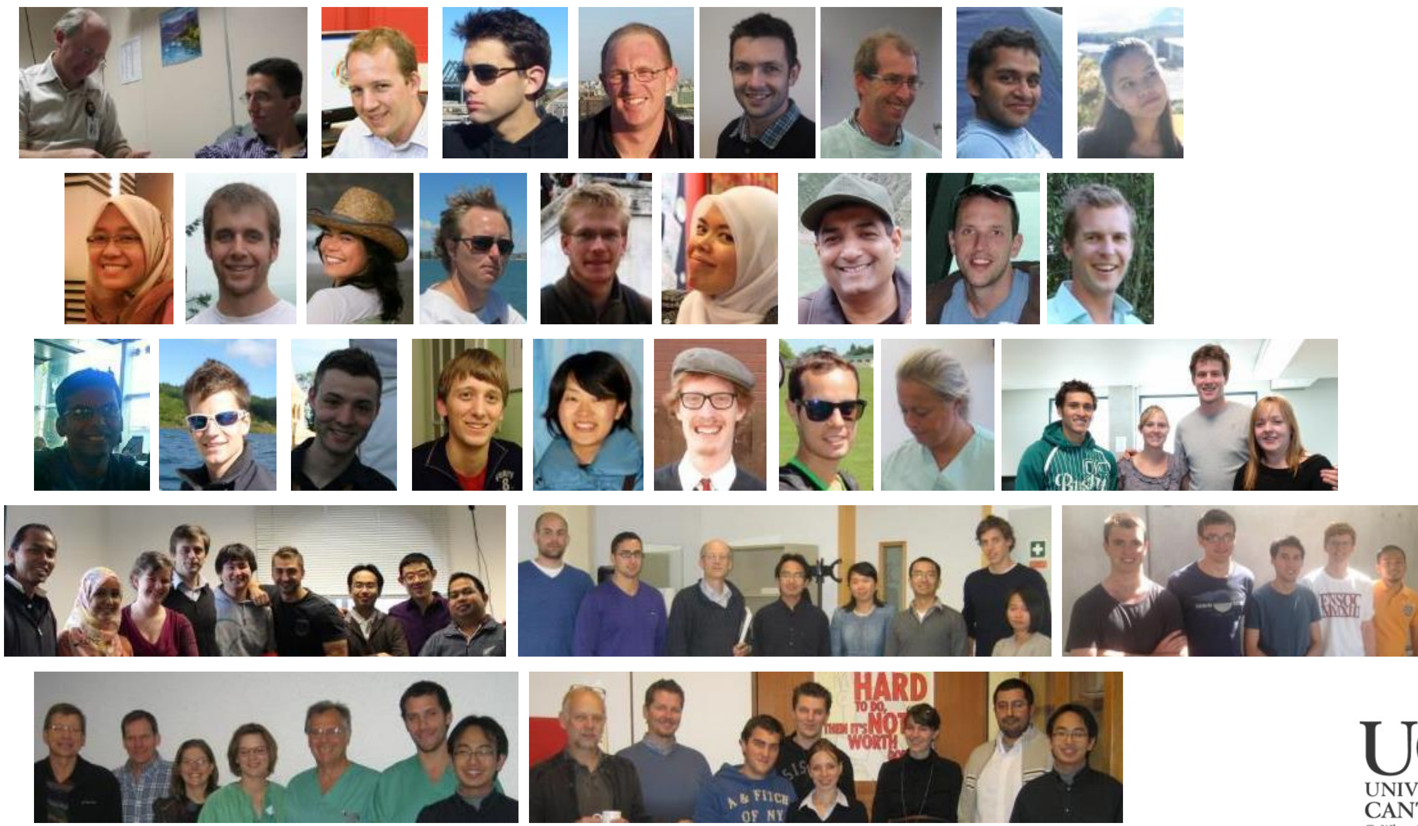

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Thank you

Messerli FH: **Chocolate Consumption, Cognitive Function, and Nobel Laureates.** *New England Journal of Medicine* 2012, **367:**1562-1564.

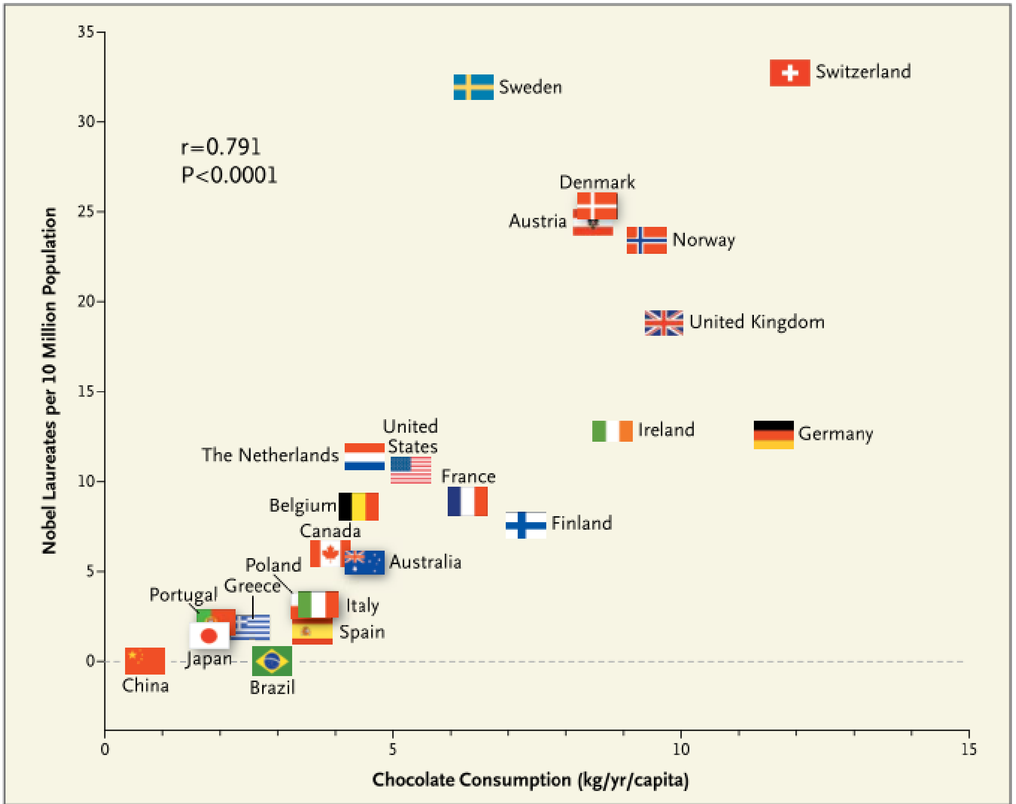

Figure 1. Correlation between Countries' Annual Per Capita Chocolate Consumption and the Number of Nobel Laureates per 10 Million Population.

Thank you

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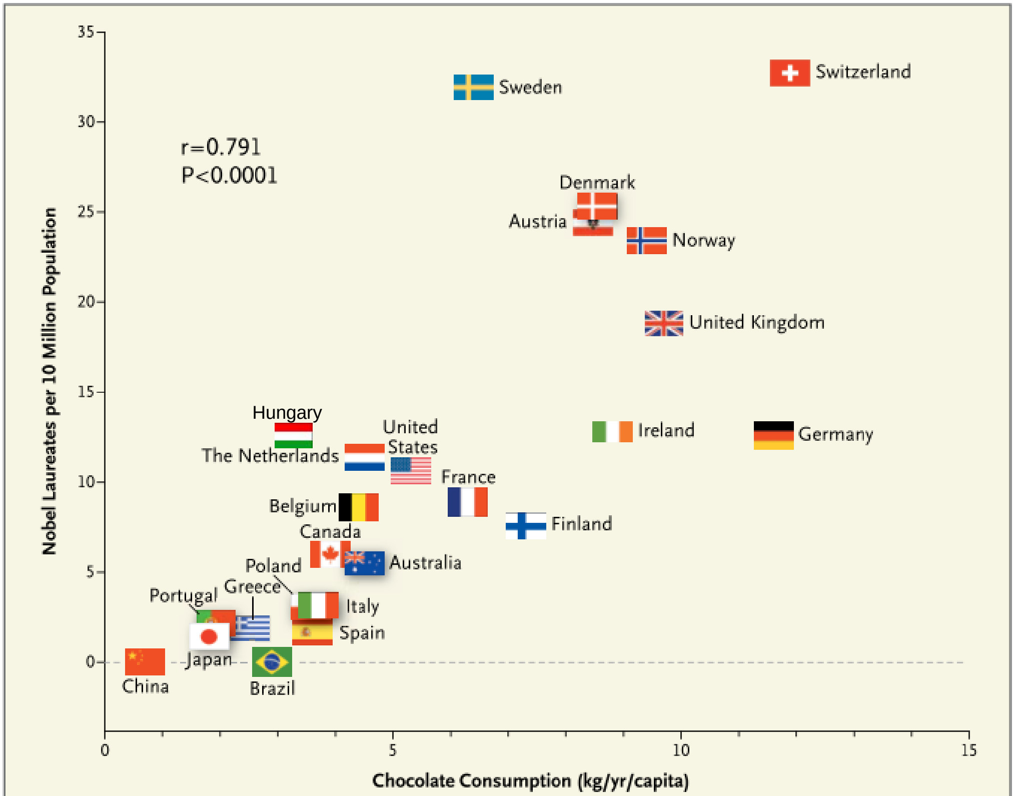

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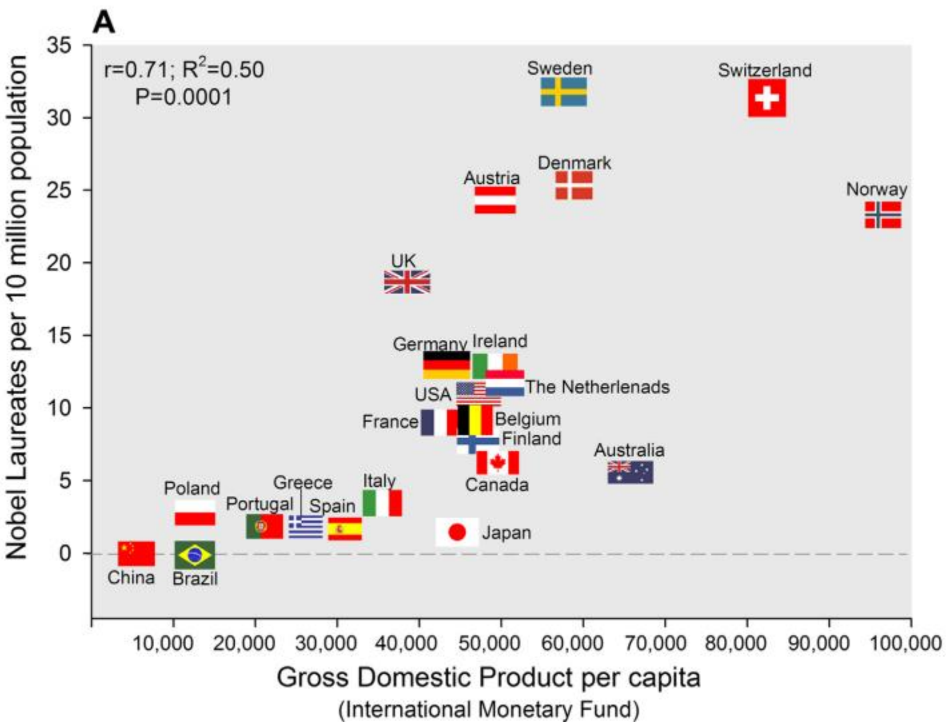
Just FYI

Ortega FB: The intriguing association among chocolate consumption, country's economy and Nobel Laureates. *Clinical Nutrition* 2013, **32**:874-875.



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Maurage P, Heeren A, Pesenti M: Does Chocolate Consumption Really Boost Nobel Award Chances? The Peril of Over-Interpreting Correlations in Health Studies. *The Journal of Nutrition* 2013, **143:**931-933.