Optimal PEEP selection in Mechanical Ventilation using EIT

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Carleton University - 2009/11 M.A.Sc

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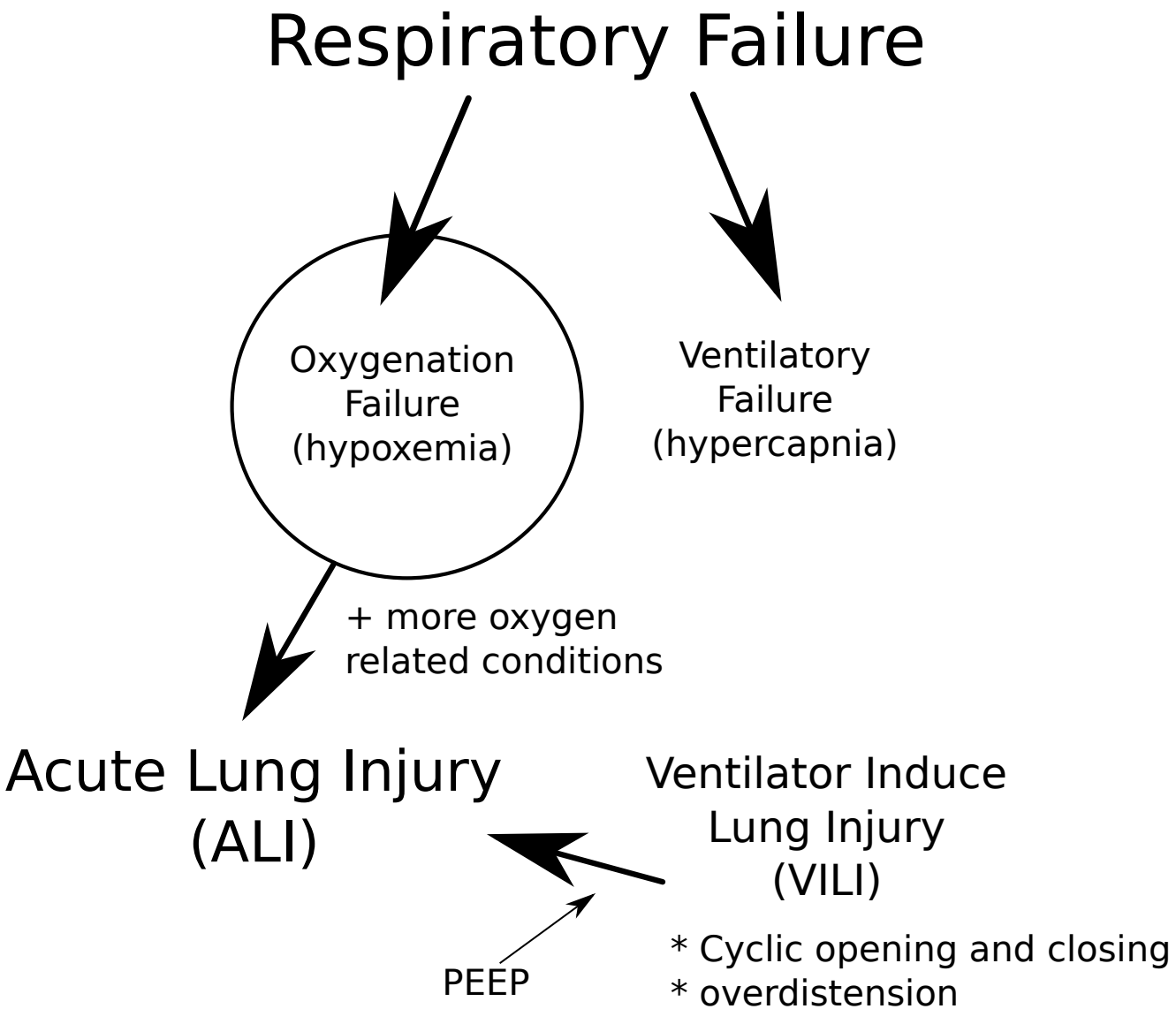
- Novel Aspects:
  1. Use of short recruitment maneuever ($\leq$ 2min)
  2. Regional Inflection Points used
  3. Use of Inflection Points within an automated classification system

ALI & VILI


Respiratory Failure
Oxygenation Failure (hypoxemia)
Ventilatory Failure (hypercapnia)
+ more oxygen related conditions
Acute Lung Injury (ALI)
Ventilator Induce Lung Injury (VILI)
PEEP
* Cyclic opening and closing
* overdistension

Respiratory Function Models

$$P_{ao} = \frac{V}{C} + \dot{V}R + \ddot{V}I - P_{mus} \tag{1}$$

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- To remove other components this thesis data did two things:
  1. Slow Constant Flow
  2. Antheysia

Pressure-Volume Curves

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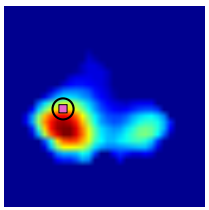
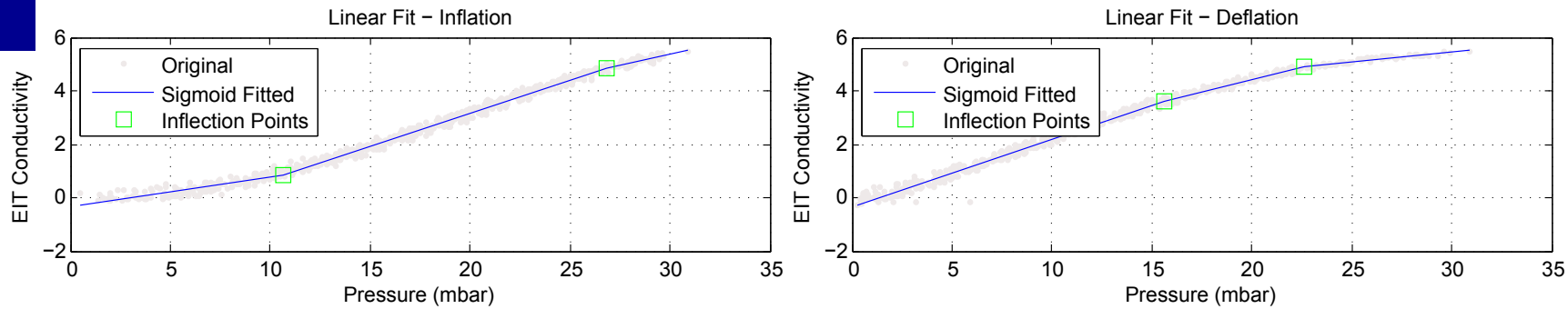
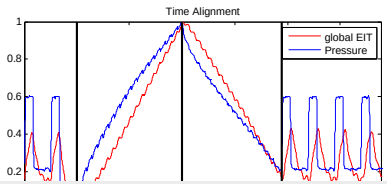




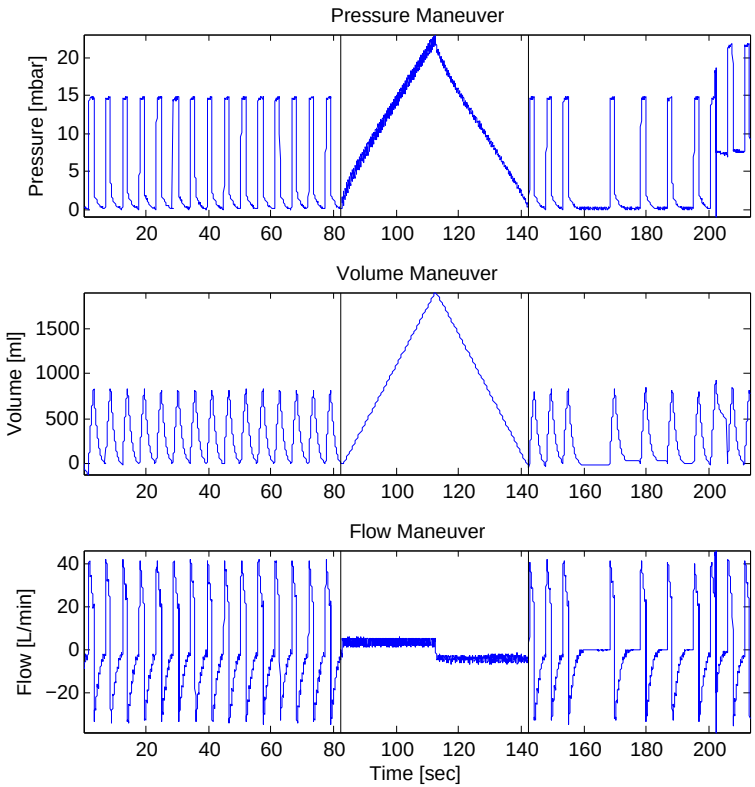
(e) Linear Fit of PI data



Data used

Data used:

- 26 patients
- low constant flow maneuver (4 L/min)
- start 0 mbar $\rightarrow$ 35 mbar / 2L



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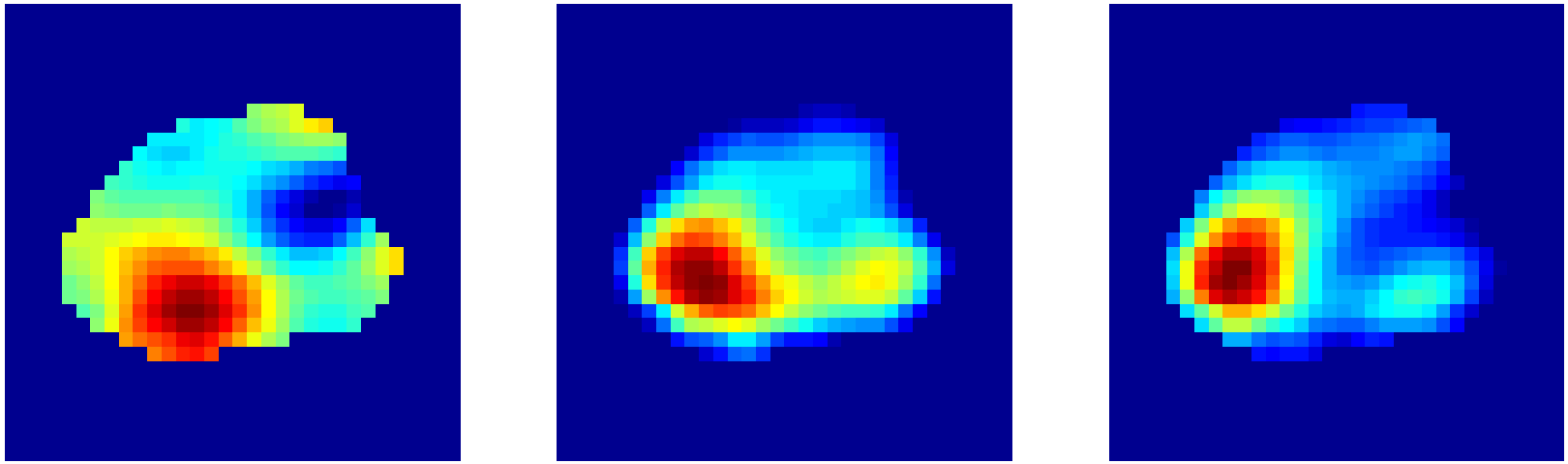

(a) Start of Inflation (b) Max Pressure (c) End of Deflation

Figure: Example reconstruction using the GREIT methods of a healthy lung patient (patient 7).

Contributions

- Automated IP calculation

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- Rule-base Fuzzy Logic Classifier

IP Calculation

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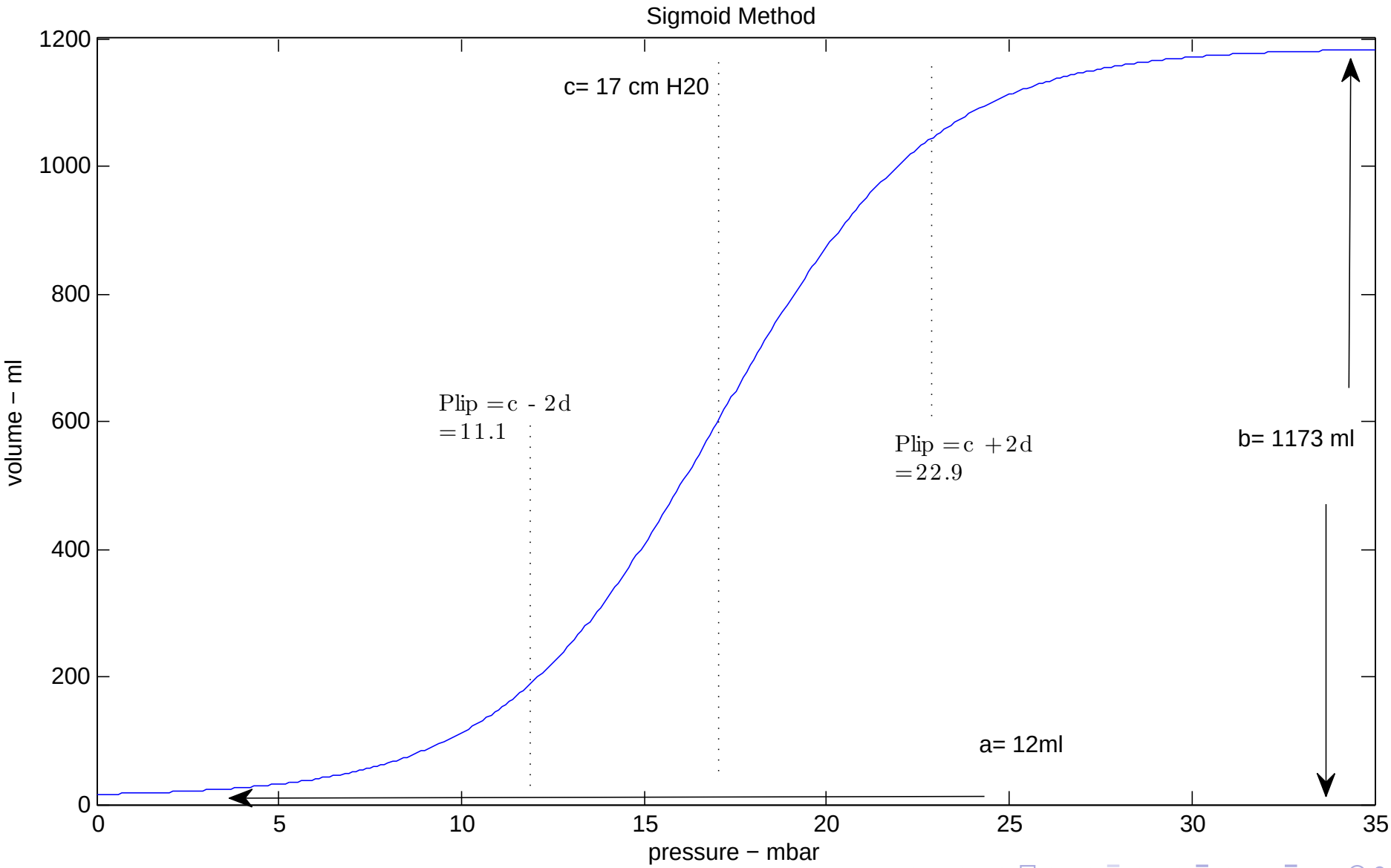
3. 3-piece linear spline method

Multiple methods were implemented for comparison reasons.

Sigmoid Method



Visual Heuristics

- Clinicians used this method to locate Inflection Points from global PV curves.
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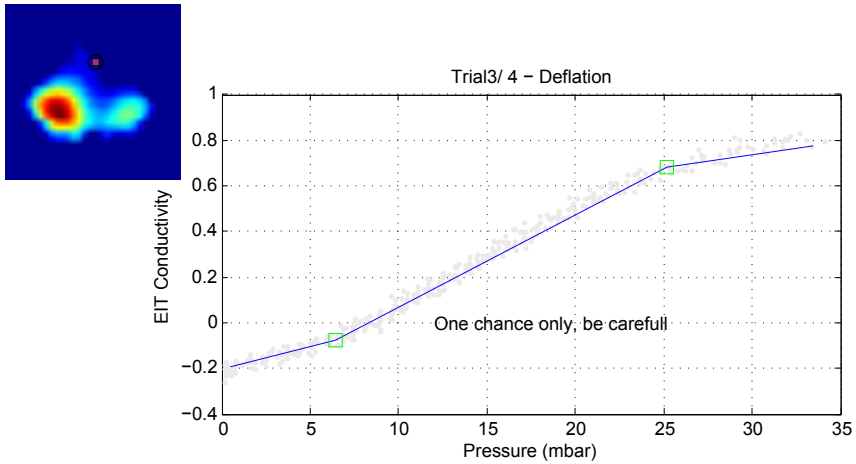
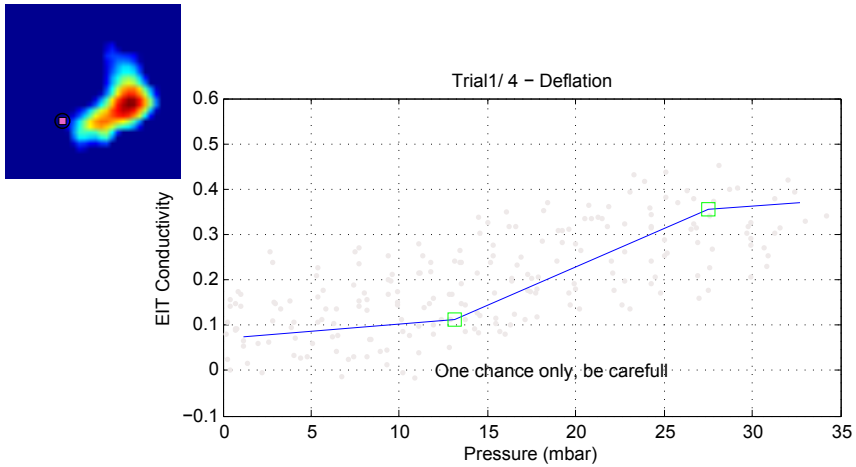
- This thesis:
  1. 5 participants
  2. Fit in linear manner to get closest to all the data points

Visual Heuristic





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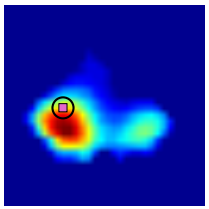

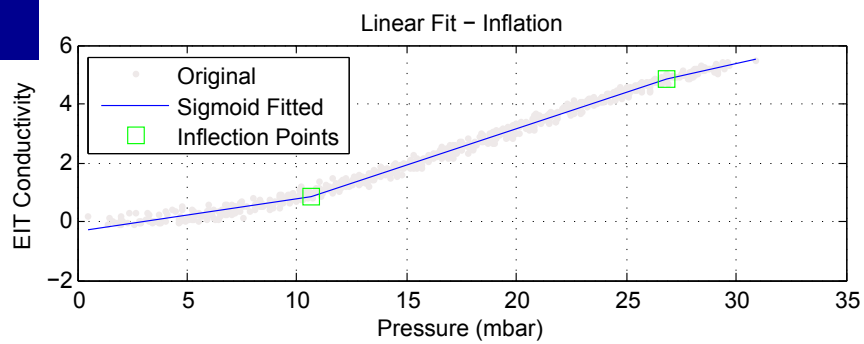

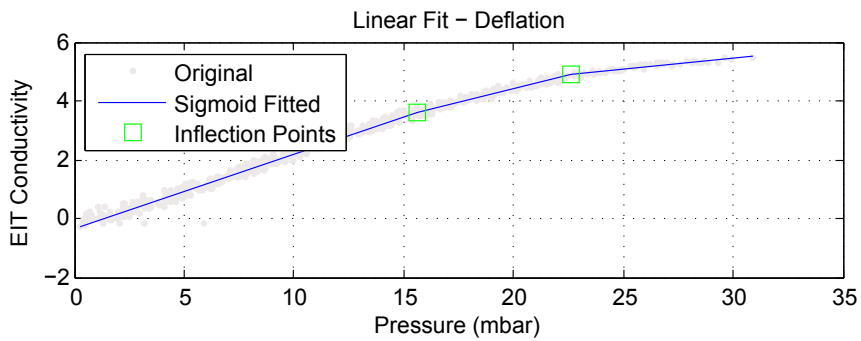

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3. Premise Calculation (Application of IF-THEN)
4. Defuzzification and Optimization

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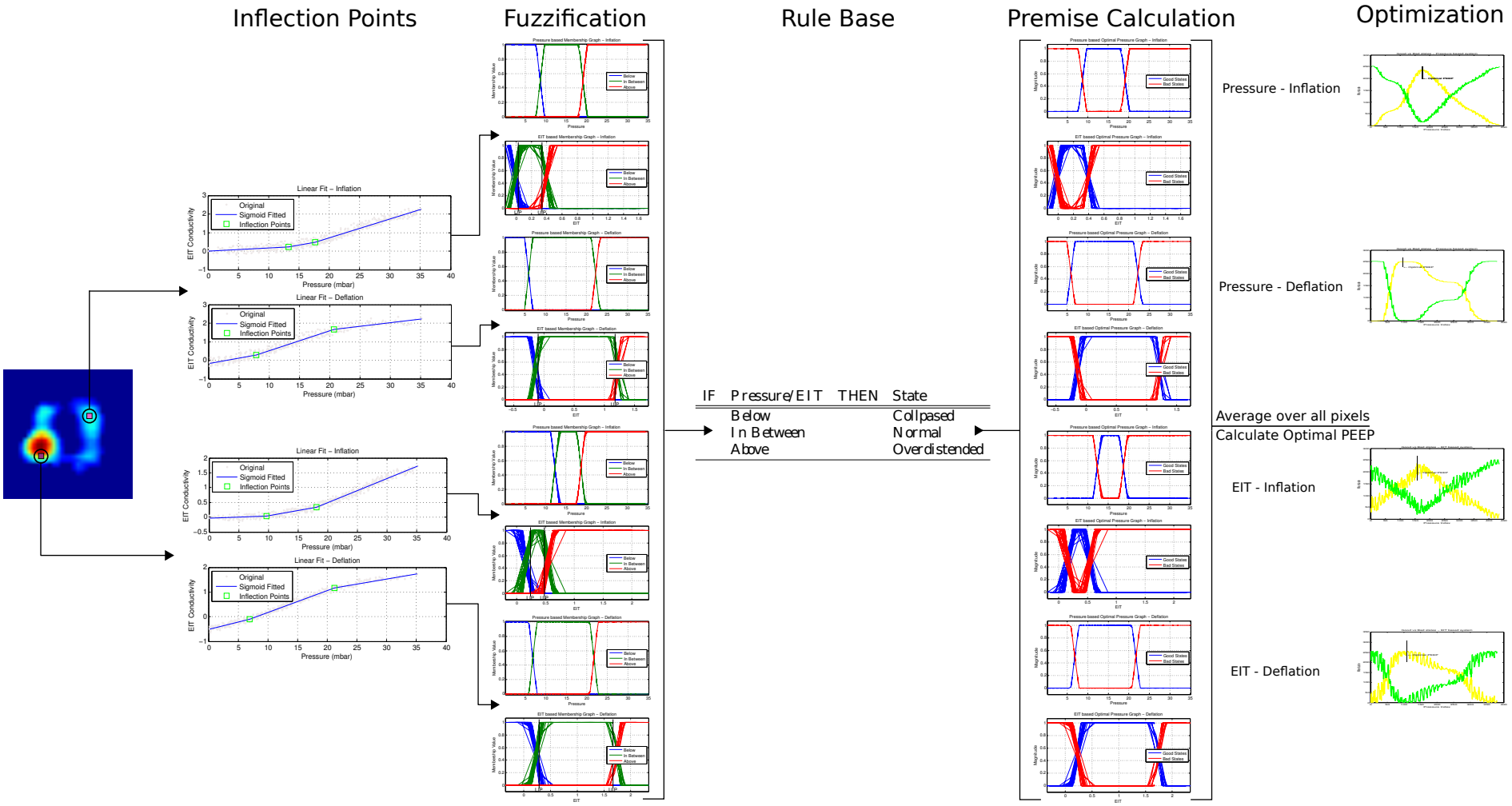

▸ Inference and Defuzzification

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IP were taken from the 3-piece linear optimization portion and used in the creation of the fuzzification graphs.

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Membership	Input 1 (mbar)	Input 2 (mbar)	Input 3 (mbar)	Input 4 (mbar)
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In Between	-2+LIP	LIP	UIP	2+UIP
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Table: Details on creating the trapezoidal based fuzzy membership functions

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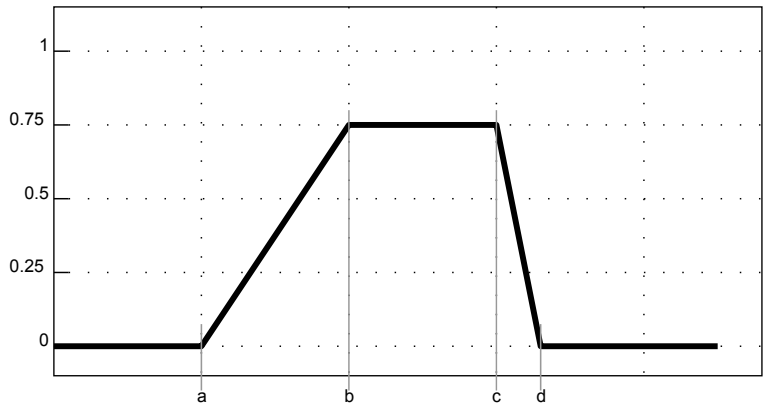

Figure: Trapezoidal Fuzzy Membership graph

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Upon averaging over lung region MAX value between the difference of 'Good' and 'Bad' states is performed to locate the PEEP. ▸ Fuzzy Logic Schematic

Sigmoid vs. Linear

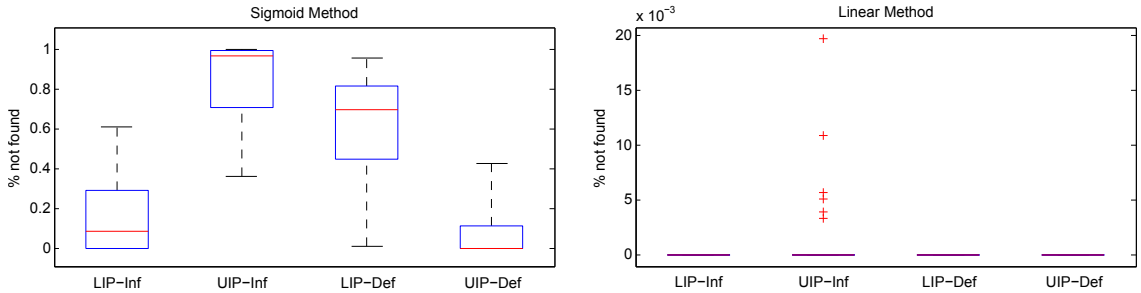

Figure: How frequent each sigmoid and linear method are not able to find IP.

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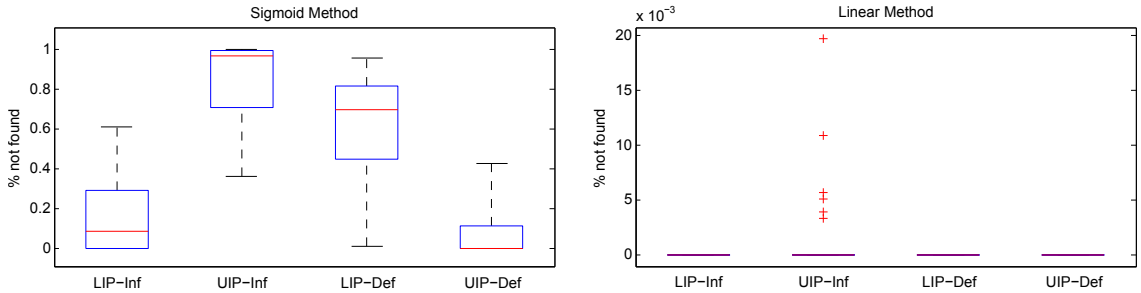

Figure: How frequent each sigmoid and linear method are not able to find IP.

	Mean	Std	Median
LIP - Inflation	1.47	3.02	1.50
UIP - Inflation	-6.80	2.54	-6.82
LIP - Deflation	4.07	1.84	4.07
UIP - Deflation	-2.37	2.24	-2.78

Table: Difference between Sigmoid and Linear Method

Linear vs. Visual Heuristics

- $Difference = Linear\ IP - Visual\ Heuristic\ IP$

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- *Difference* = *Linear IP* − *Visual Heuristic IP*
- −0.6247mbar for LIP −0.4662mbar for UIP

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- best average $= 0.016$mbar worst average $= -1.507$mbar

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- −0.6247mbar for LIP −0.4662mbar for UIP
- best average = 0.016mbar worst average = −1.507mbar
- Provides insight to accuracy of linear method

Hetergenaity

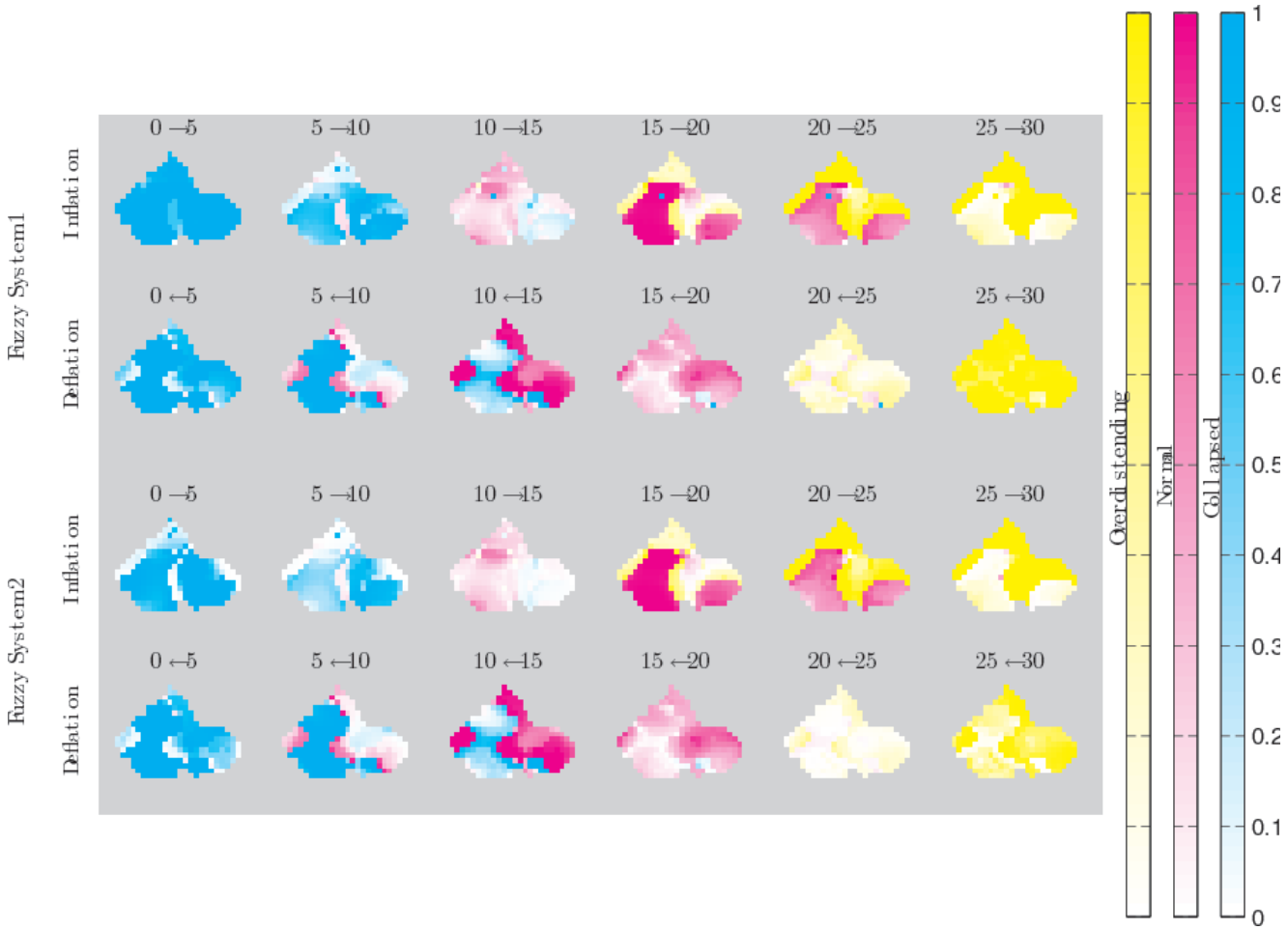
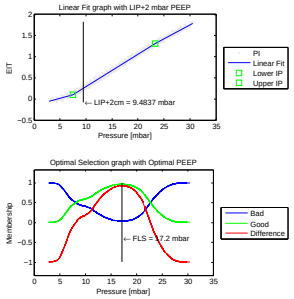
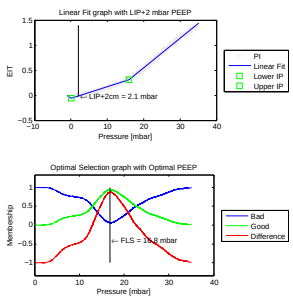


Figure: Progressive change of lung state with pressure

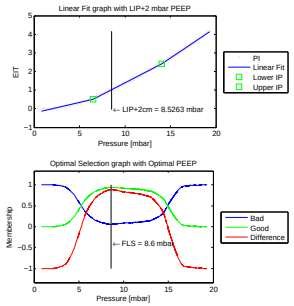
LIP+2 vs FLS



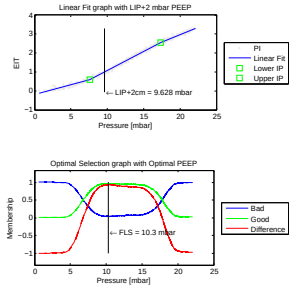
(a) Patient 12



(b) Patient 16



(c) Patient 8



(d) Patient 17

Figure: Global PI curve with LIP, UIP, and the LIP+2 mbar pressure and the Fuzzy optimal selection with according FLS based pressure.

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ending

- Fuzzy Logic Schematic