From Data to Insight: Revealing Lung Health with Patient-Specific Models

J. Cheng(ucahhej@ucl.ac.uk), F.A. DiazDelaO
Clinical Operational Research Unit (CORU), Department of Mathematics, UCL

Intensive Care Unit (ICU) Data

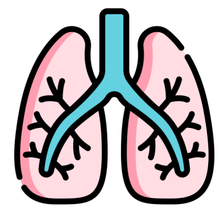
ICU ventilators and monitors generate **complex, high-volume data** influenced by multiple factors.

However, much of this data remains **unused**.

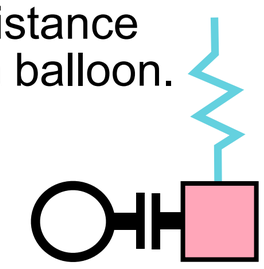
Clinical decisions rely on **limited snapshots** rather than the full data picture.

Patient-Specific Lung Model

Our lung model divides the lungs into 4 components to simulate the behaviours of **stiff lungs**.



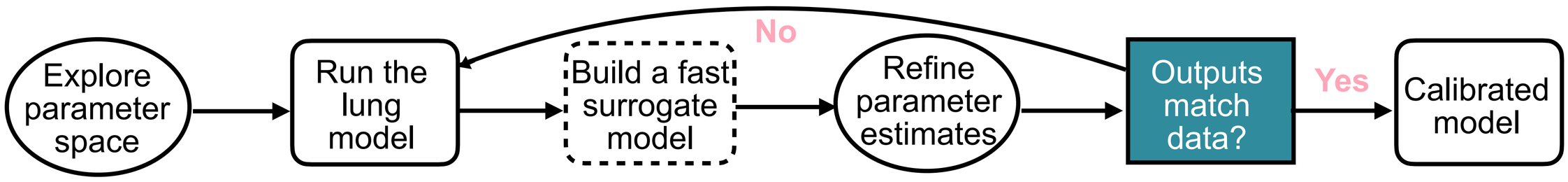
Each component contains a **resistor** and a **capacitor**, which represent airflow resistance and pressure storage like a tube and a balloon.



But the parameters of the model **differ between patients** and cannot be measured directly.

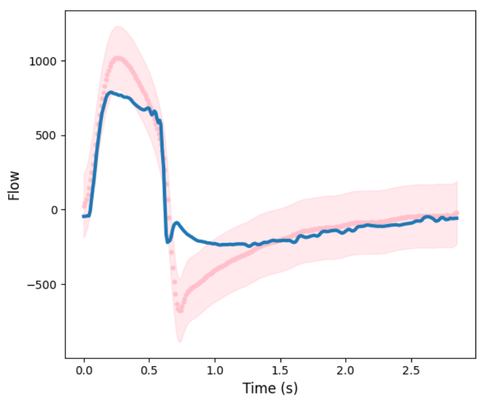
How do we infer patient-specific parameters? Calibration.

Calibration **adjusts model parameters** so that model **outputs match observed data**. It also accounts for uncertainty arising from many factors, such as measurement error and model limitations.



- **History Matching** iteratively rules out implausible parameter values, restricting attention to regions consistent with observed data.
- A surrogate model (e.g., **Gaussian process emulation**) provides a fast statistical approximation of the original model, allowing more efficient exploration of the parameter space.

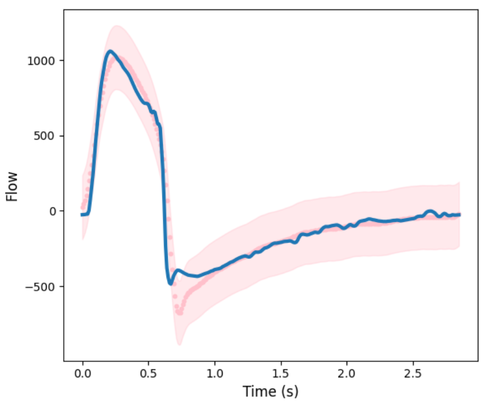
When Data Arrives…



Observed ICU data from ventilators.

Uncertainty from many factors.

Model outputs before and after calibration



Before Calibration **After Calibration**

Without calibration, the model may describe **an "average" patient**, not **the individual** in the ICU.

When new data arrives…

- We propose **Sequential Bayesian History Matching (SBHM)**, a sequential extension that **reuses information** from the previous breath to calibrate the model for the next.
- Can be more than **twice as fast as** starting from scratch.
- Suitable for **real-time monitoring** and **adaptive control**.

Conclusions

- Calibration updates model parameters to keep the model aligned with observed ICU data for **each patient**.
- Reusing previous information enables efficient, dynamic calibration, **continuously refining the parameters**.
- This approach has the potential to provide clinicians with real-time, patient-specific insights to **support decision-making**.

Reference: Cheng, J., DiazDelaO, F.A. and Hristov, P.O., 2025. Dynamic model updating through reliability-based sequential history matching. Mechanical Systems and Signal Processing, 232, p.112689.