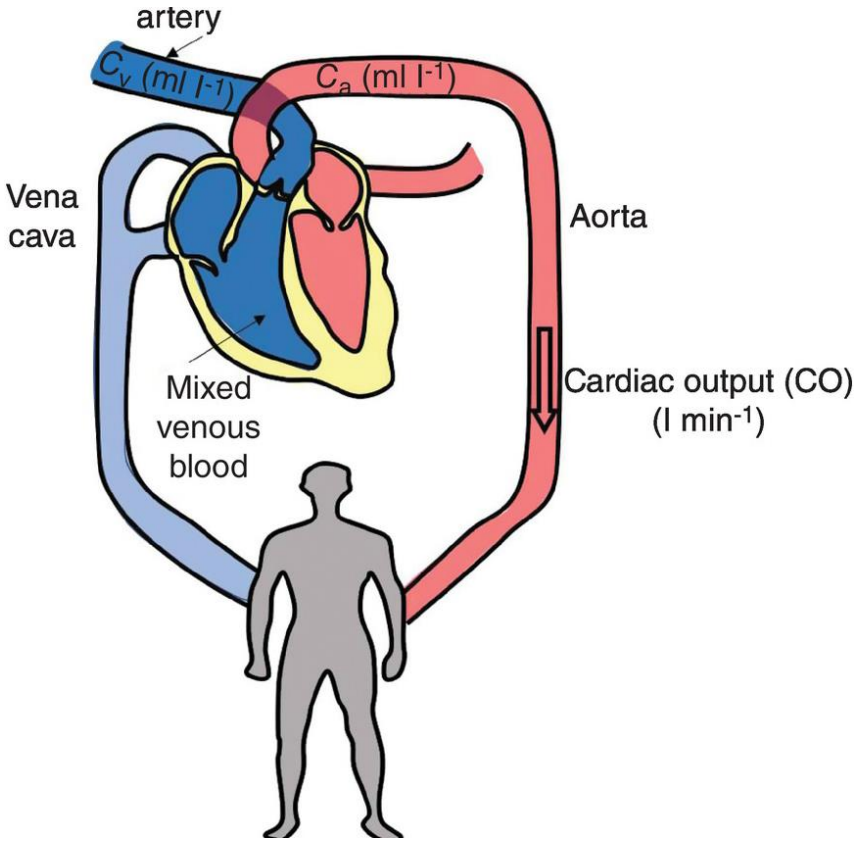


Predicting Cardiac Output from Arterial Blood Pressure

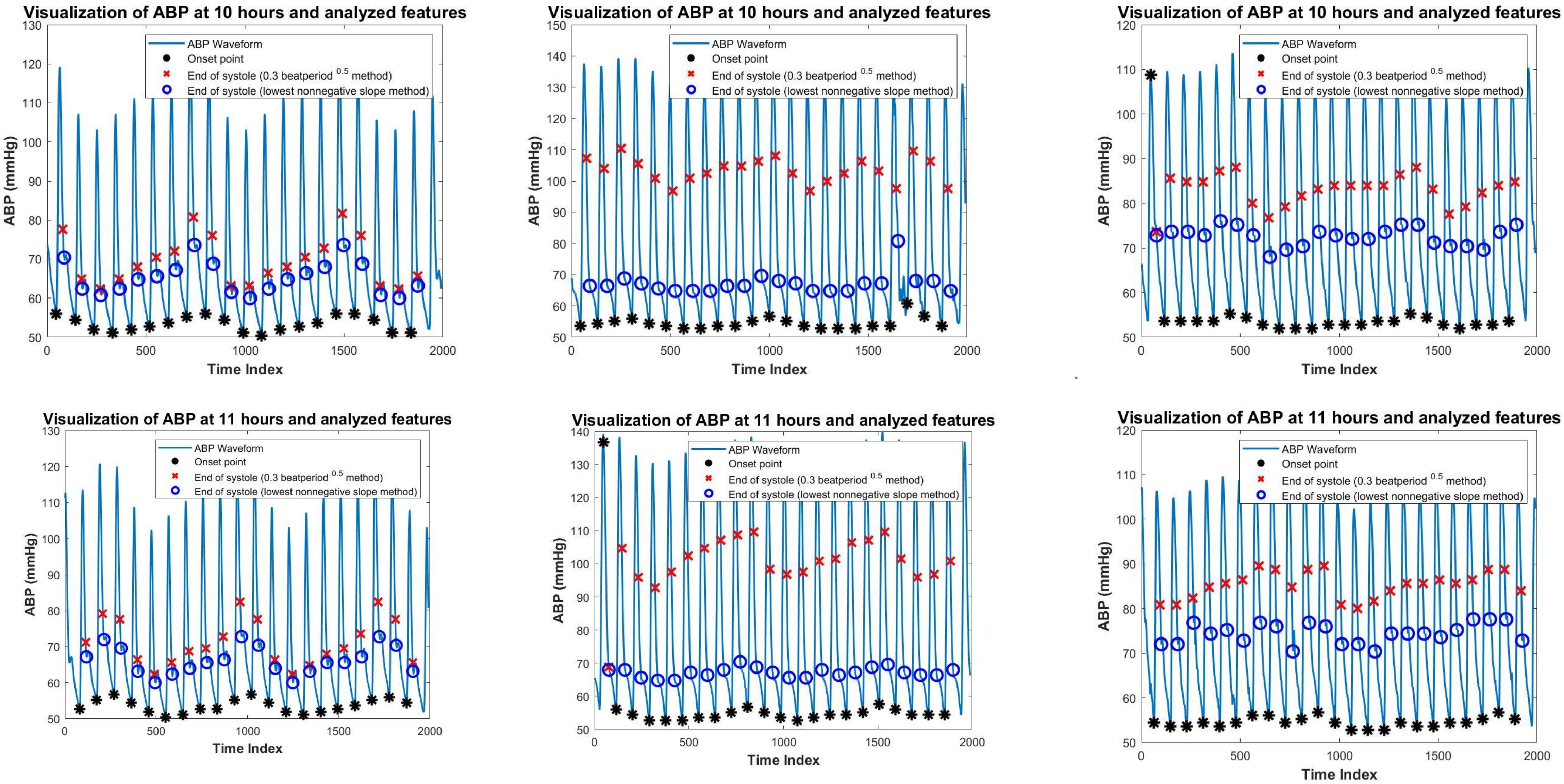
Team 9

Sejal Ghate

Zixu Han

Yongzhi Sun

ABP and derived features from three subjects for 20 peaks



#s00020 #s00214 #s05114

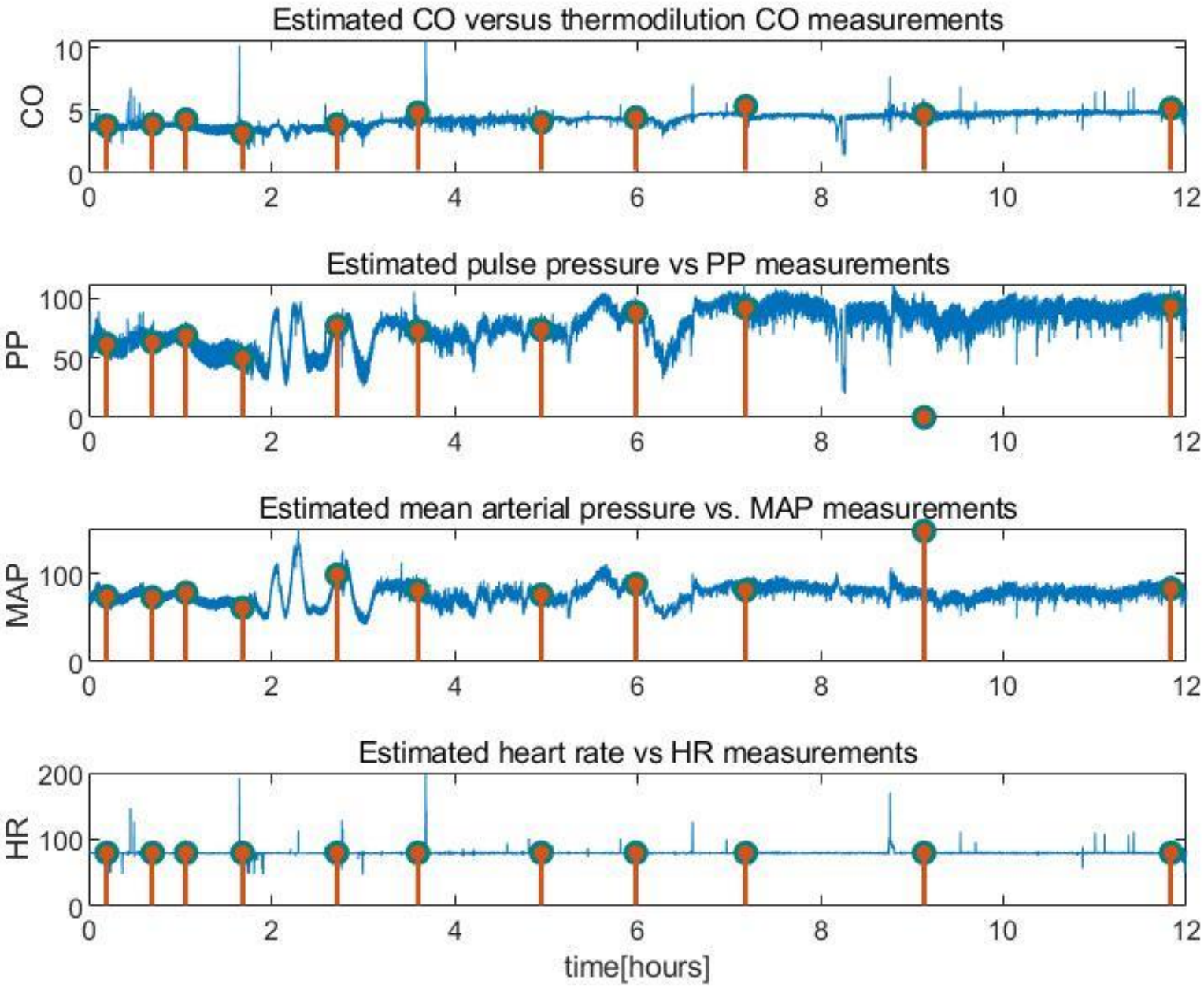
Estimated CO from Liijestrandand algorithm - #s00020

Liljestrand estimation: Estimator 5

$$\text{Stroke volume} = \frac{k \times (SBP - DBP)}{(SBP + DBP)}$$

- Continuous: Estimated CO
- **Calibration (C2): Calibration_factor=COtd(1)/ Uncalibrated_CO**
- Stem: COtd measurements at different times

- Continuous PP, MAP and HR are derived from computed feature matrix
- Stem plot: PPs, MAPs, HRs that are measured at the same time as COtd measurements



Repeat CO estimation with three other algorithms

- **Systolic area with Kouchoukos correction**

$$\text{Stroke volume} = k \times \left(1 + \frac{Duration_{Systole}}{Duration_{Diastole}}\right) \times \int_{Systole} ABP(t)dt$$

- **Herd**

$$\text{Stroke volume} = k \times (MAP - DBP)$$

- **Parlikar**

$$\mathrm{CO}_n = C_n \left(\frac{\Delta P_n}{T_n} + \frac{\overline{P}_n}{\tau_n}\right)$$

$$\tau_n = \frac{\overline{P}_n T_n}{2\left(\overline{P}_n - DAP_n\right) - \Delta P_n}$$

Calibration: *the same as the one used in Liljestrand algorithm (C2)*

Calibration: least-square-error

$$C_n = \gamma_1 + \gamma_2 \overline{P}_n \ .$$

$$Cn = \frac{COtd\_nonzero}{corresponding\ estimated\_CO}$$

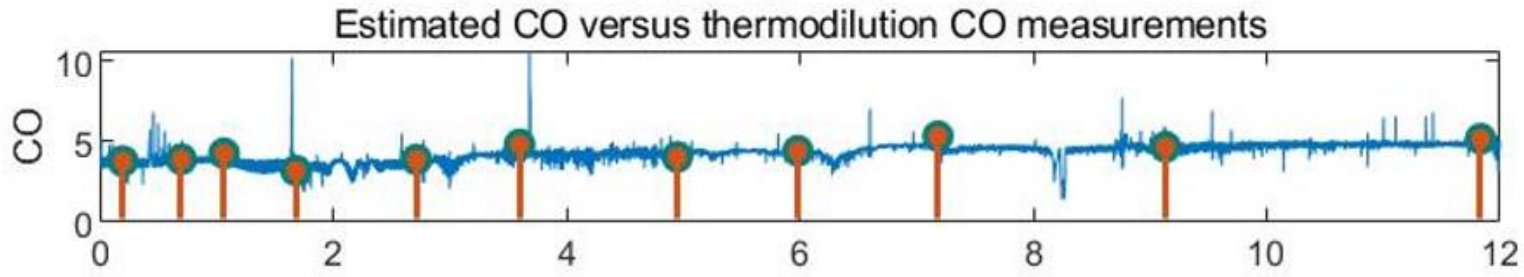
$\overline{MAP}$=corresponding mean arterial pressure

$$\gamma 2 = \frac{\sum_{i=1}^{n}(MAPi - \overline{MAP}) * (Ci - \bar{c})}{\sum_{i=1}^{n}(MAPi - \overline{MAP})\text{^}(2)}$$

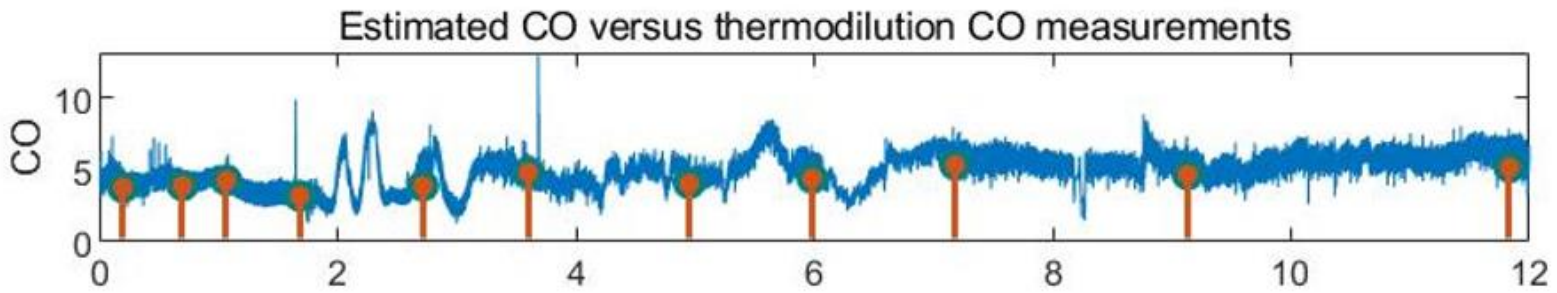
$\gamma 1 = \bar{c} - \gamma 1 * \overline{MAP}$

Estimated CO - #s00020 for the first 12 hours

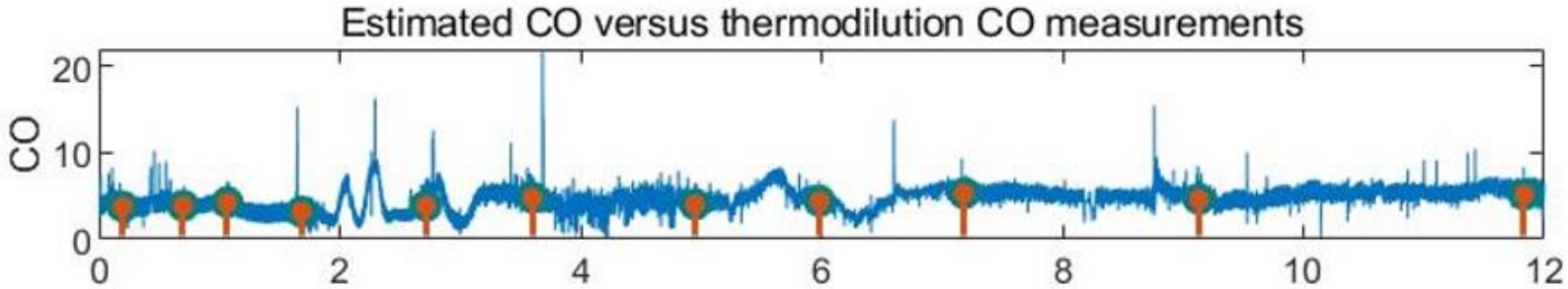
Liljestrand



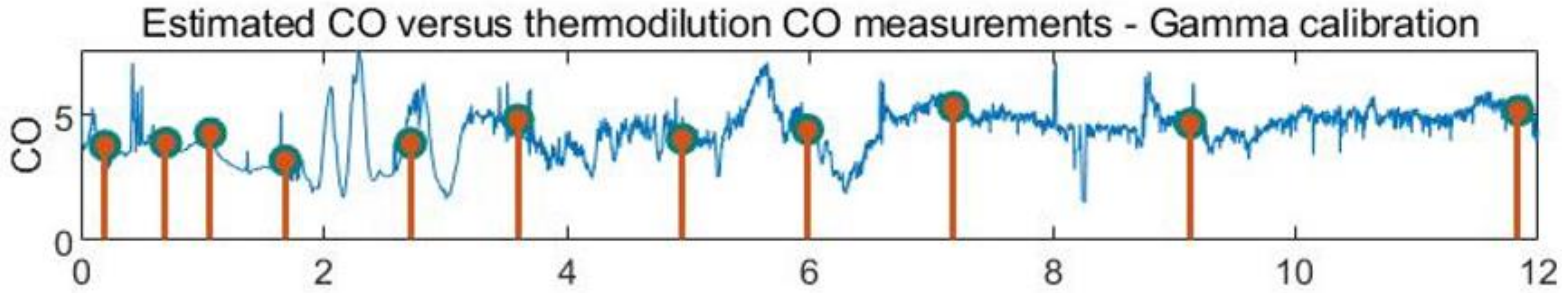
Systolic area with Kouchoukos correction



Herd



Parlikar with filt_order = 15



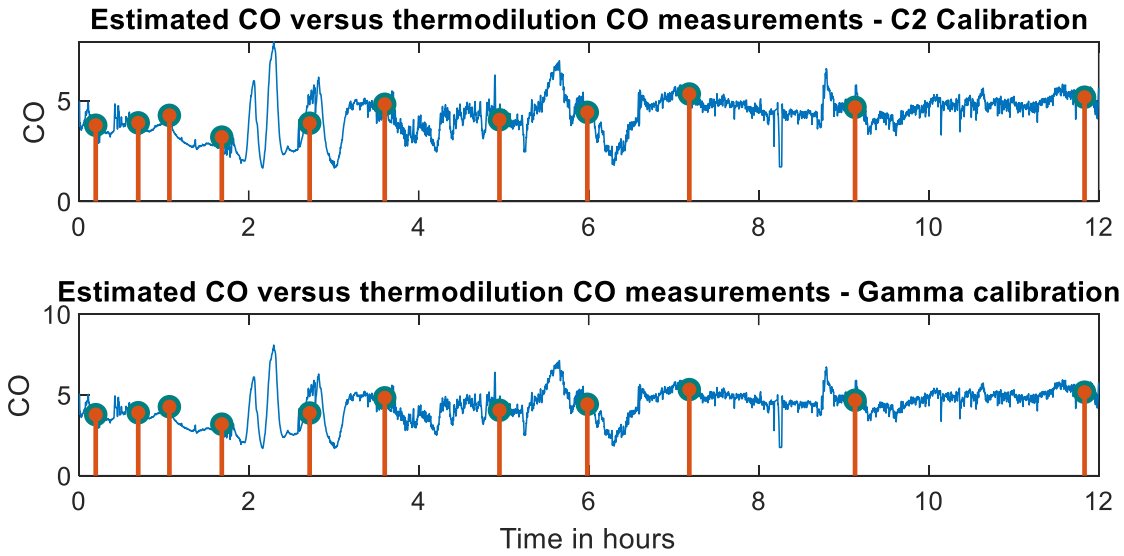
CO Calibration using Parlikar's method:

- Sliding Window approach:
  - Window size 21
  - Filtering used: filter order 15
  - τ calculated for each index within the window
  - Least squares solution used to assign the value obtained from the p equation
  - This value is assigned to center most index in the window
  - Window slides by one index
  - To account for indexes which cannot be mid-points for any window (left and right extreme indexes), Values interpolated to nearest non-zero value (i.e, first non-zero and last non-zero values respectively)

$$\tau_n = \frac{\bar{P}_n T_n}{2\left(\bar{P}_n - DAP_n\right) - \Delta P_n}$$

$$\beta = \frac{\sum_{i=n-a}^{i=n+a} \bar{P}_i y_i}{\sum_{i=n-a}^{i=n+a} \bar{P}_i^2}$$

- Calibration: C2 and least square 'ϒ' calibration

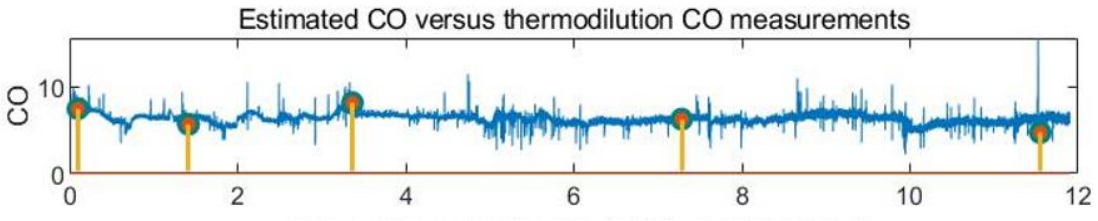


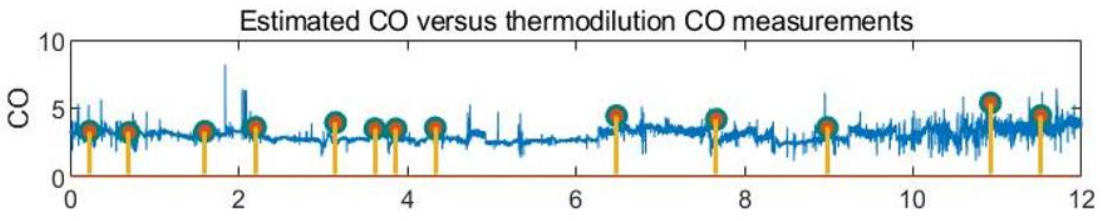
Estimated CO with two other subjects

#s00214

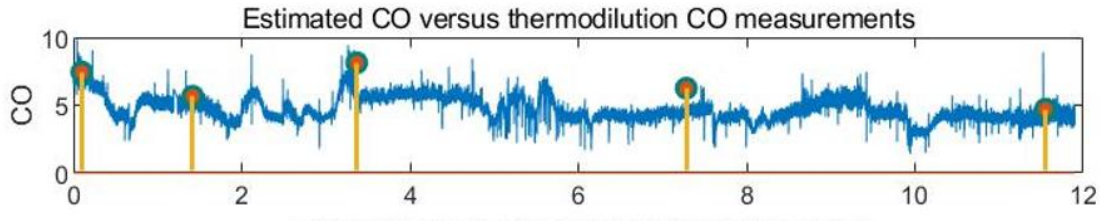
#s05114

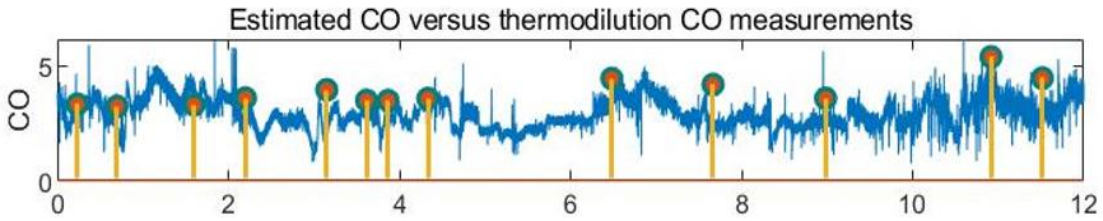
Liljestrand



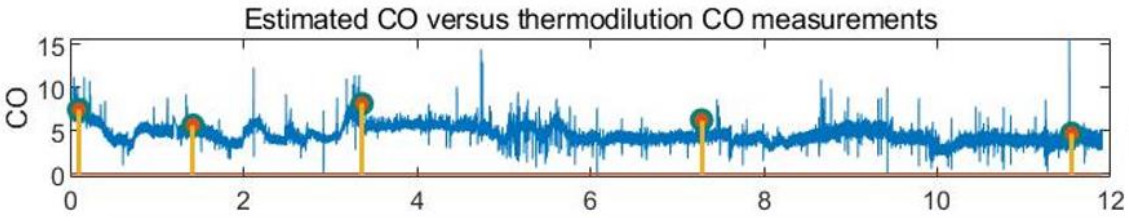


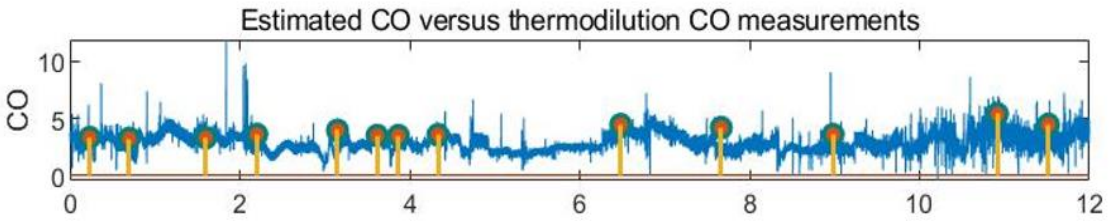
Systolic area with Kouchoukos correction



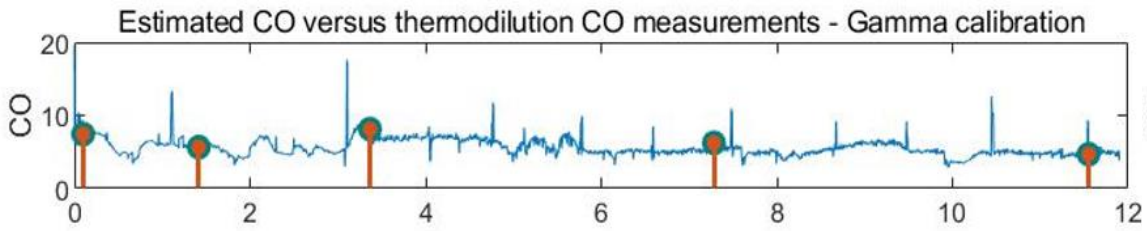


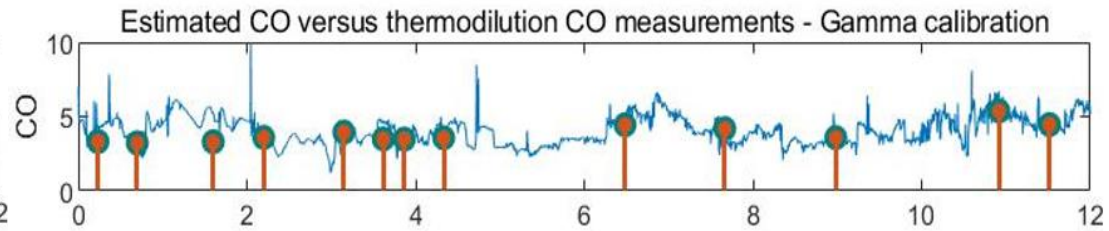
Herd





Parlikar



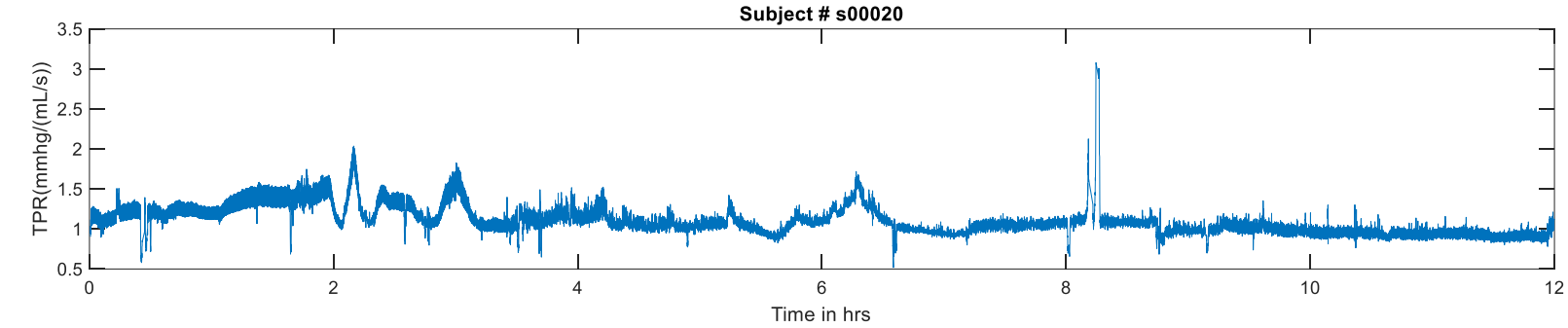


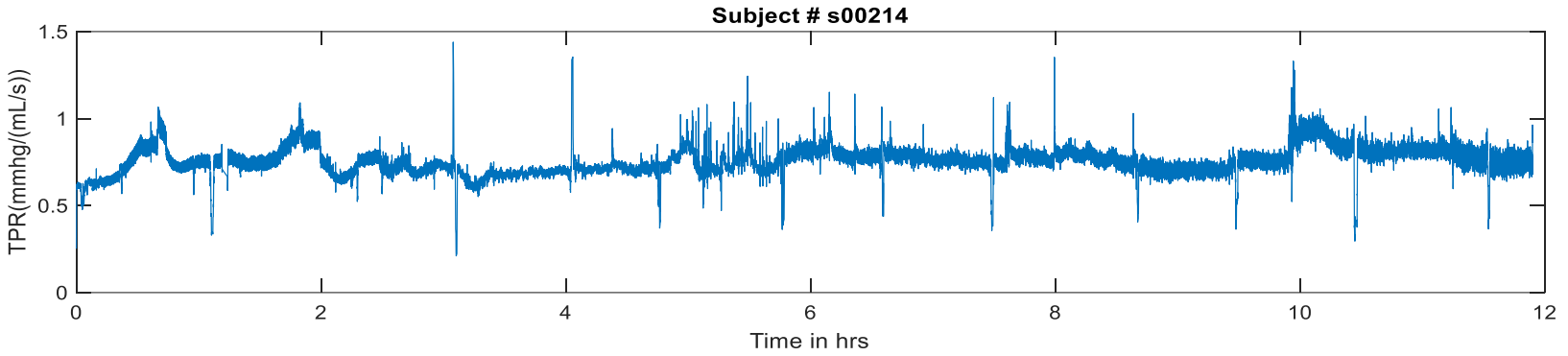
Total peripheral resistance calculated after Parlikar estimation

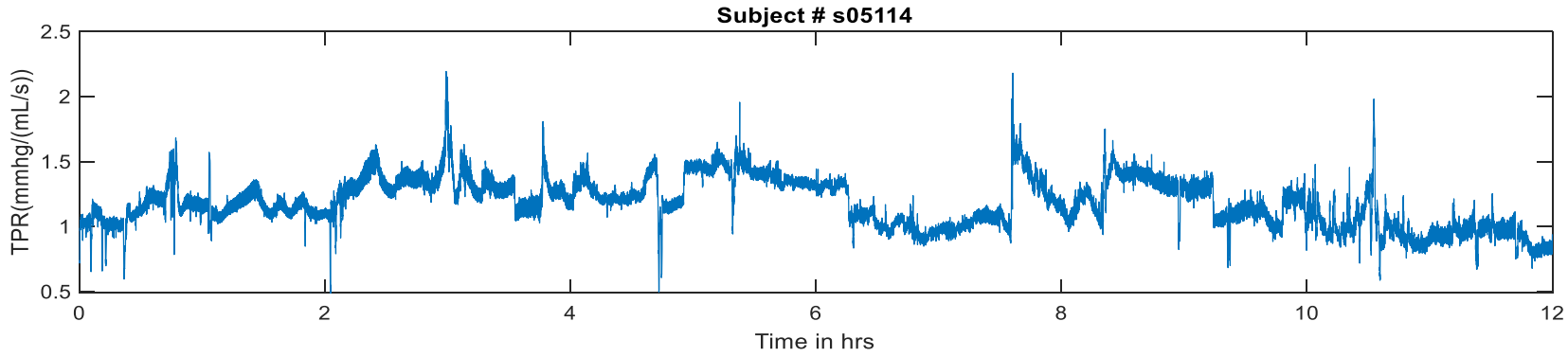
Formula used for TPR:

$$R_n = \frac{\overline{P}_n}{\mathrm{CO}_n - C_n \frac{\Delta P_n}{T_n}} .$$

- Feature matrix extracted from the modified estimated_co code
- Calculation performed on variables of this feature matrix
- Appropriate conversion applied for TPR units to mmHg/(mL/s)







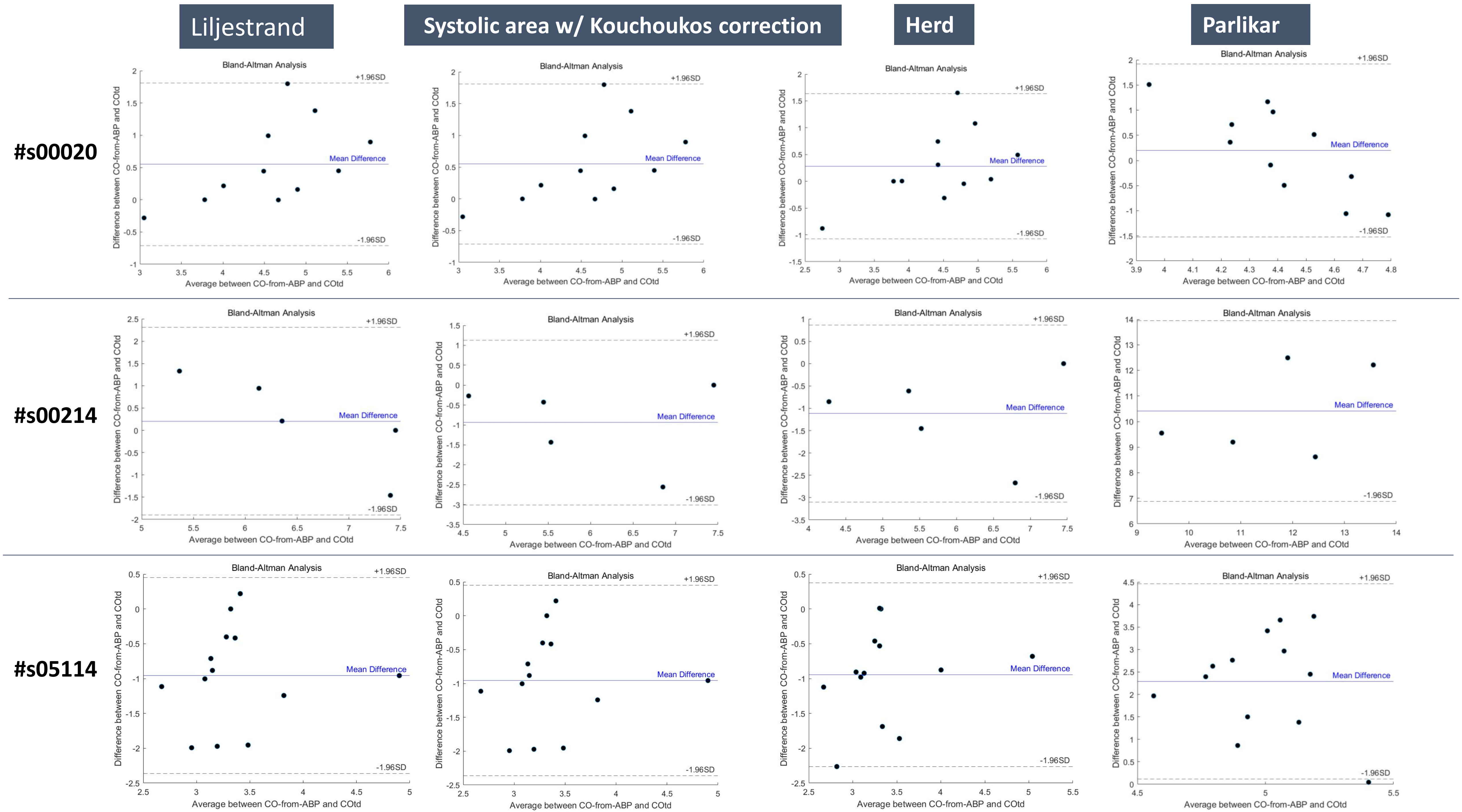
Bland-Altman Analysis for algorithm comparison based on each paired COtd-estimated_CO

- Error Distributions of each paired CO-from-ABP and COtd for each algorithm
- X axis-Mean value: (Estimated CO + Cotd)/2
- Y axis-Difference: Estimated CO – Cotd
- Mean Difference: Sum of Y /no.Cotd
- 95% limits of agreement: Mean Difference$\pm$1.96SD

$$S(x,y) = \left(\frac{S_1 + S_2}{2}, S_1 - S_2\right)$$

	#00020	#00214	#05114
Liljestrand	-0.750/+0.457	-1.902/+2.310	-1.950/+0.282
SA with correction	-0.713/+1.812	-3.007/+1.130	-2.362/+0.449
Herd	-1.077/+1.637	-2.265/+0.376	-2.265/+0.376
Par	-1.520/+1.918	6.878/+13.949	0.122/+4.457

95% limits of agreement


Liljestrand
Systolic area w/ Kouchoukos correction
Herd
Parlikar
#s00020
#s00214
#s05114
Bland-Altman Analysis
Difference between CO-from-ABP and COtd
Average between CO-from-ABP and COtd
+1.96SD
Mean Difference
-1.96SD

Difficulties and interesting observations associated with project:

- Sample selection: Unlike sample 20, the waveforms of many samples are chaotic and do not show waveforms similar to those expected, feature extraction might not always be the most accurate due to presence of ectopic beats and outliers in the signal.

Our solution: Manually screen the data and find a better waveform for analysis

- There are questions about the selection of V2 and V3 algorithms

Our solution: Choose the simpler V3 algorithm among the two methods

- Extreme values appear in the Parlikar estimated COs

Our solution: Increase the filter order to 15 in estimate_co_v3 function.

- What's interesting? : Higher frequency waveform data! Need not always be clean, is very noisy, and due to different instruments used needs a lot of 'reverse engineering' to find similarities in different data frames.

Individual contribution:

01

Sejal Ghate :
Question 1,3,5,6

02

Zixu Han :
Question:3,4,5

03

Yongzhi Sun:
Question: 1,2,3