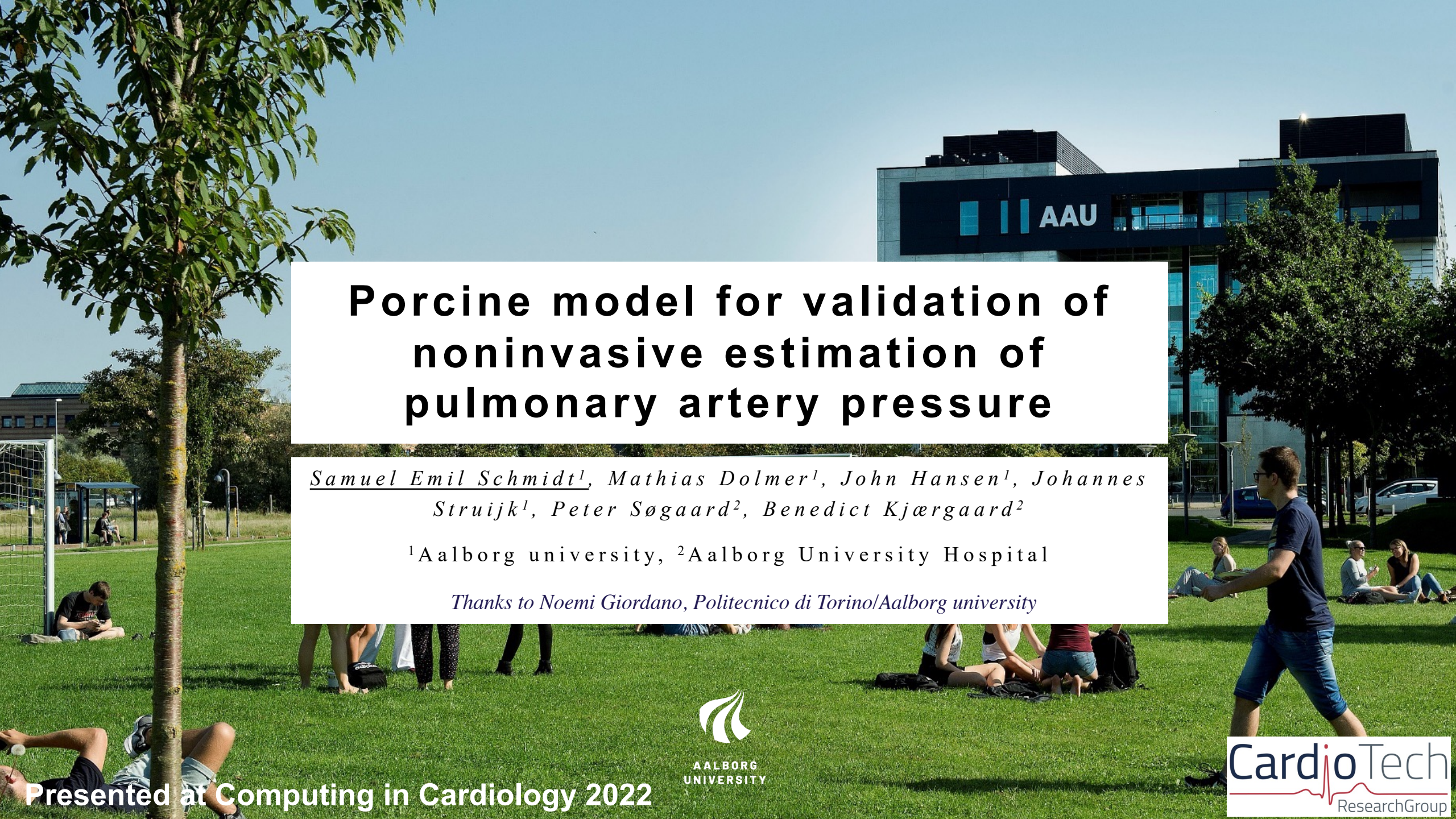
Porcine model for validation of noninvasive estimation of pulmonary artery pressure

Schmidt, Samuel Emil; Dolmer, Mathias Hagerup; Hansen, John; Struijk, Johannes Jan; Søgaard, Peter; Kjærgaard, Benedict



Porcine model for validation of noninvasive estimation of pulmonary artery pressure

Samuel Emil Schmidt[1], Mathias Dolmer[1], John Hansen[1], Johannes Struijk[1], Peter Søgaard[2], Benedict Kjærgaard[2]

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Presented at Computing in Cardiology 2022

Study aim

- Develop a model for validation of pulmonary artery pressure (PAP) estimation methods
- Prosed methods for noninvasive estimation of PAP
  - Echocardiography
  - Impedance cardiography
  - Analyses of the second heart sound (S2)

Sound Pressure Correlates of the Second Heart Sound

An Intracardiac Sound Study

By James A. Shaver, M.D., Richard A. Nadolny, M.D., James D. O'Toole, M.D., Mark E. Thompson, M.D., P. S. Reddy, M.D., Donald F. Leon, M.D., and Edward I. Curtiss, M.D.

SUMMARY

The sound pressure correlates of the second heart sound were studied in 22 patients during diagnostic cardiac catheterization. Simultaneous right ventricular and pulmonary artery pressures were recorded with equisensitive catheter-tip micromanometers together with the external phonocardiogram and ECG. In 12 patients having normal pulmonary vascular resistance (group 1), pulmonic closure sound was coincident with the incisura of the pulmonary artery pressure curve

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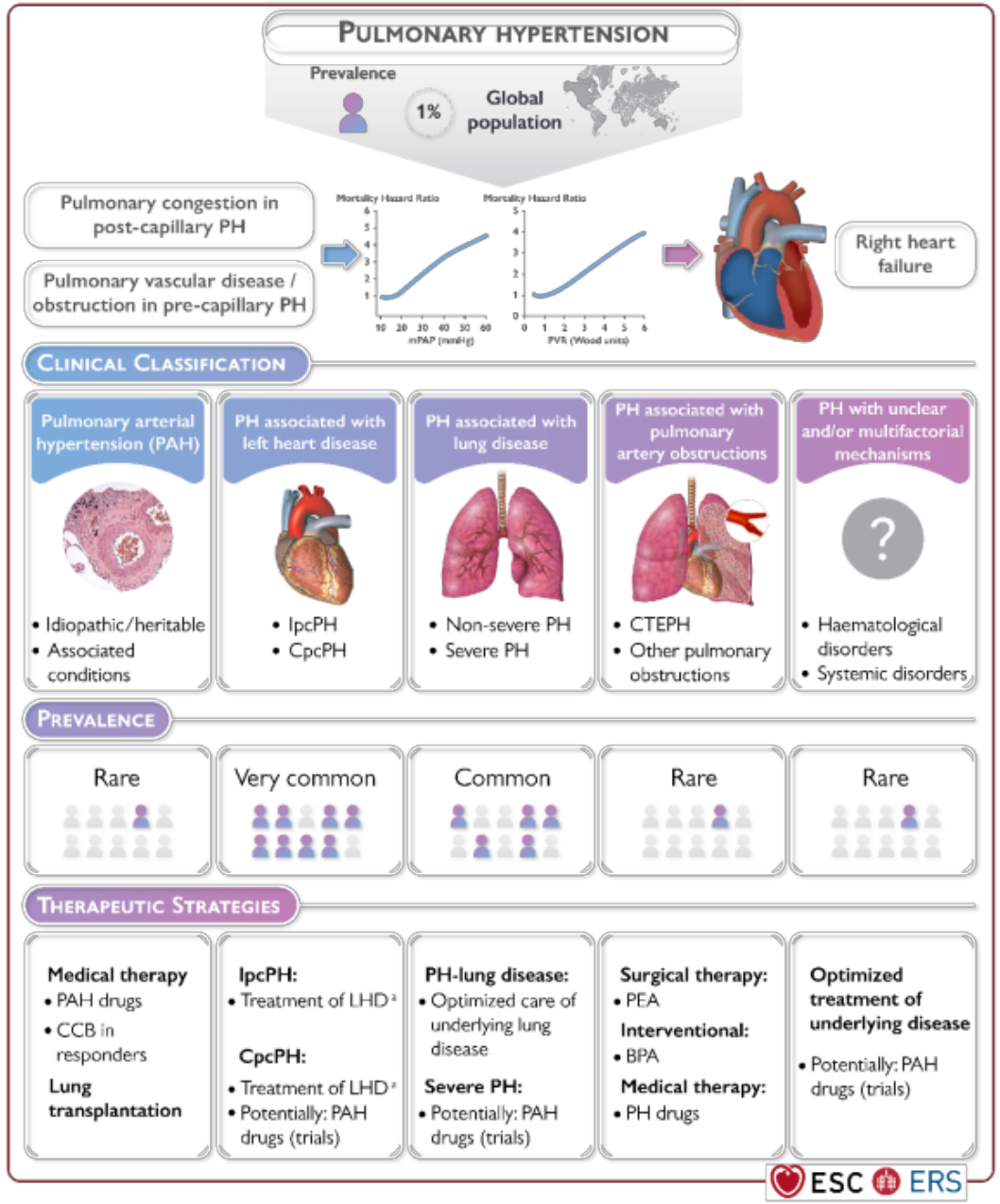
Why measure PAP noninvasively?

- Detecting pulmonary hypertension (PH)
- PH has high mortality
- PH has unspecify symptoms and multiple origins



2022 ESC/ERS Guidelines for the diagnosis and treatme

(*European Heart Journal*; 2022 – doi: 10.1093/eurheartj/ehac237 and *European Respiratory Journal*; 2022 – doi: 1

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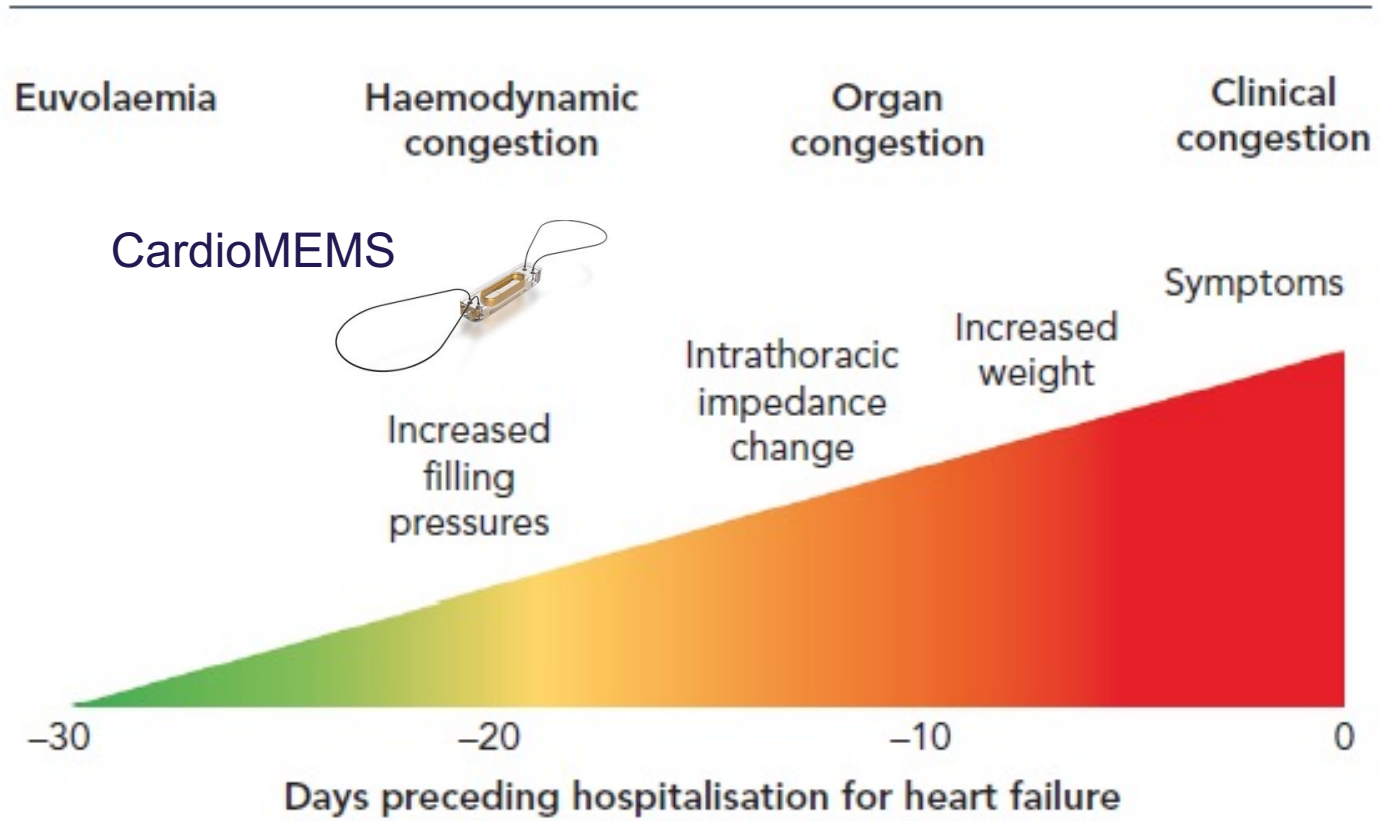
Why measure PAP noninvasively?

Detection of heart failure decompensation at the early stage



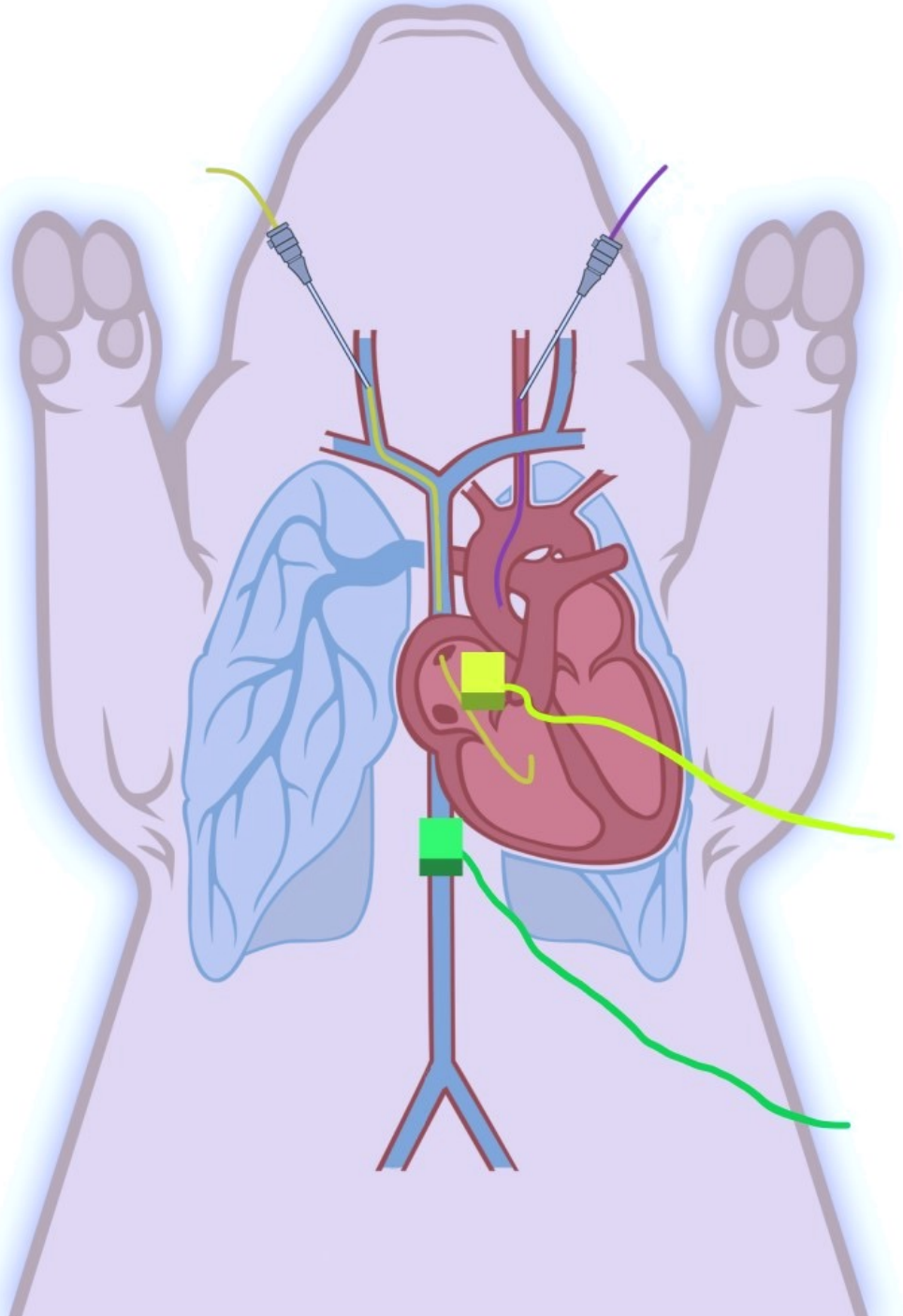
Mattia Arrigo, Petra Nijst, Alain Rudiger. Optimising Heart Failure Therapies in the Acute Setting, Cardiac Failure Review 2018;4(1)

Protocol: Set-up

- Danish Landrace pigs (Danish bacon)
  - Anaesthetized and mechanically ventilated
  - Arterial catheterization
  - Right ventricle catheterization with a Swan-Ganz catheter.
  - To avoid any effect of the catheter on the second heart sound, the pressure tip was placed in the right ventricle
  - Right ventricular systolic pressure (RVBP) was used as a surrogate of PAP.
- ECG and heart sounds from two 3-axis accelerometers was recorded using an iWorx data acquisition system

Provocation of pulmonary hypertension (Hypoxemia)

- Aim: Tricker pulmonary hypertension by pulmonary vasoconstriction*
- Method: Nitrogen asphyxiation
  - The ventilators oxygen supply was replaced with nitrogen
  - Stopping criteria: saturation in PAP or arrhythmia
- Physiology: Low O_2 concentration in the inspiration air leads to alveolar hypoxia that leads to pulmonary vasoconstriction



D Tarry, M Powell, Hypoxic pulmonary vasoconstriction, BJA Education, Volume 17, Issue 6, June 2017

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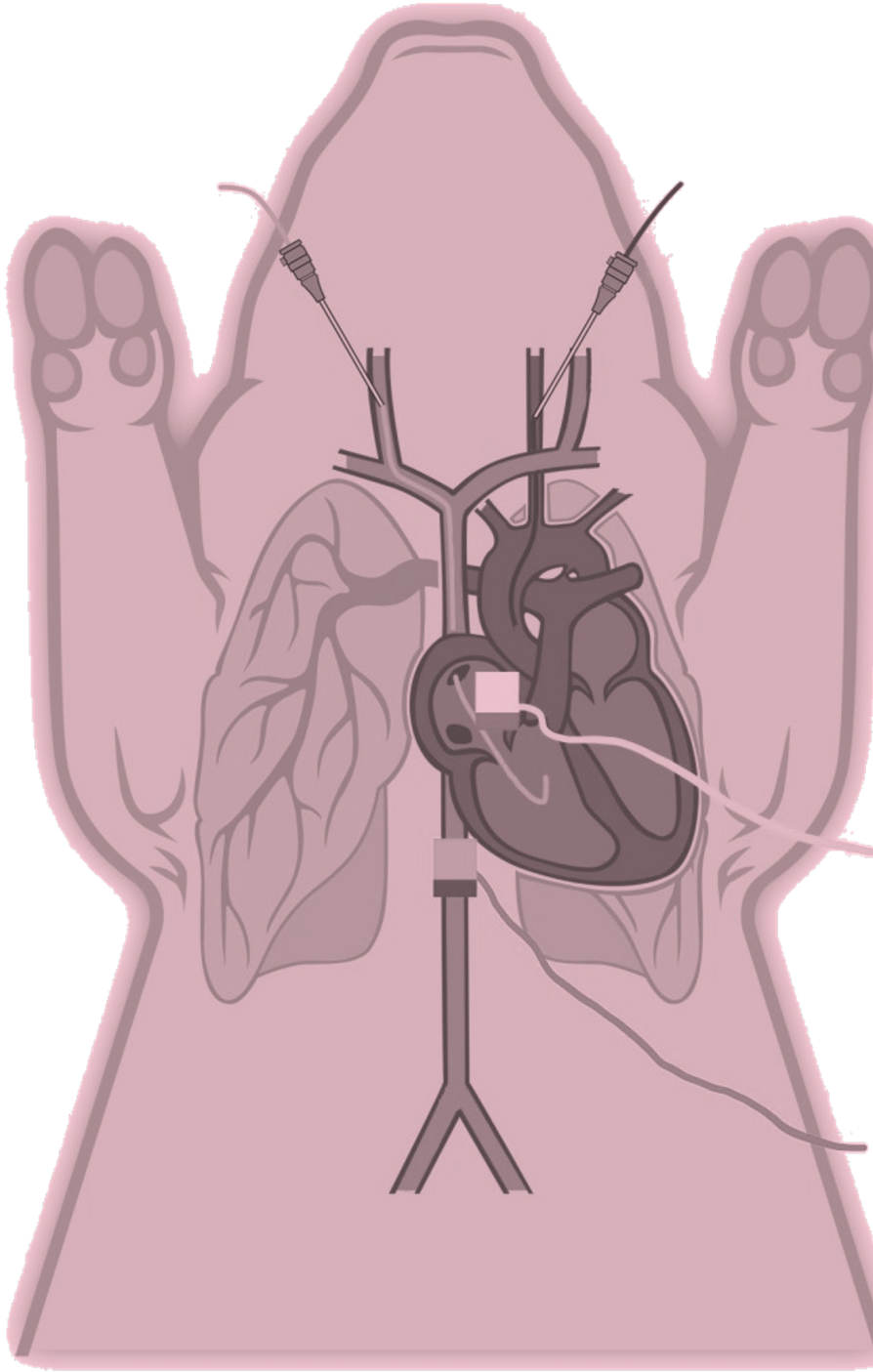
Provocation of pulmonary hypertension (Hypercapnia)

- Aim: Tricker pulmonary hypertension by pulmonary vasoconstriction*
- Method: Carbon dioxide asphyxiation
  - CO_2 was connected to the ventilator circuit and the CO_2 absorber was removed from the circuit to increase the CO_2 concentration
  - Stopping criteria was saturation in PAP or arrhythmia
- Physiology: High CO_2 concentration in the inspiration air leads to alveolar hypercapnia, which leads to pulmonary vasoconstriction

**D.A. Kregenow, E.R. Swenson. The lung and carbon dioxide: implications for permissive and therapeutic hypercapnia. European Respiratory Journal Jul 2002*

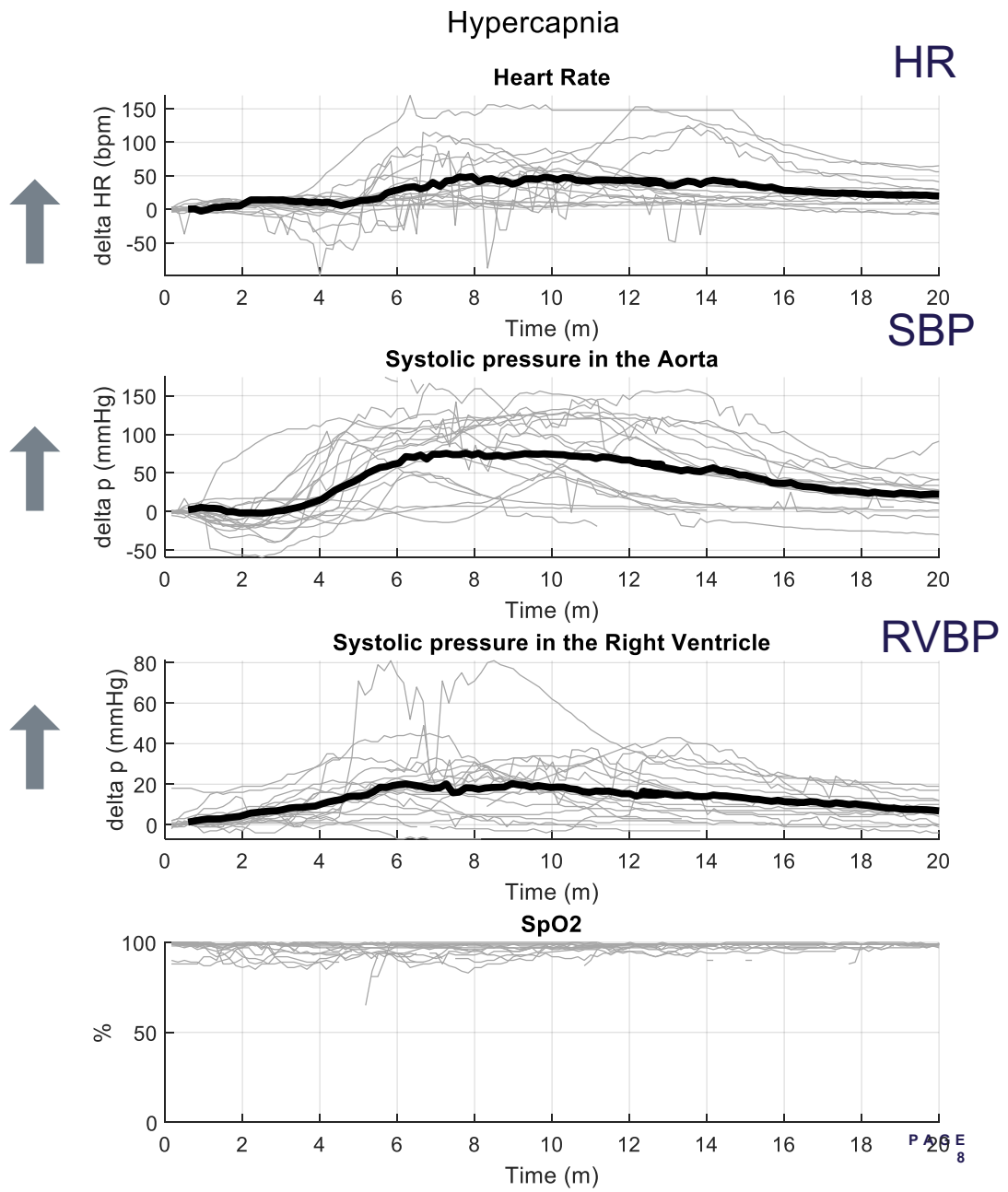


Results: Hypercapnia
(CO_2 inhalation)

- 7 pigs & 19 sessions
- Duration of CO2 inhalation: 7.1±2.4 minutes

	Baseline	Peak
↑ HR*	76.58±22 bpm	149.80±50 bpm
↑ SBP*	120.2±21 mmHg	223.7±52 mmHg
↑ RVBP*	27.21±11 mmHg	54.38±24 mmHg

* p<0.0001

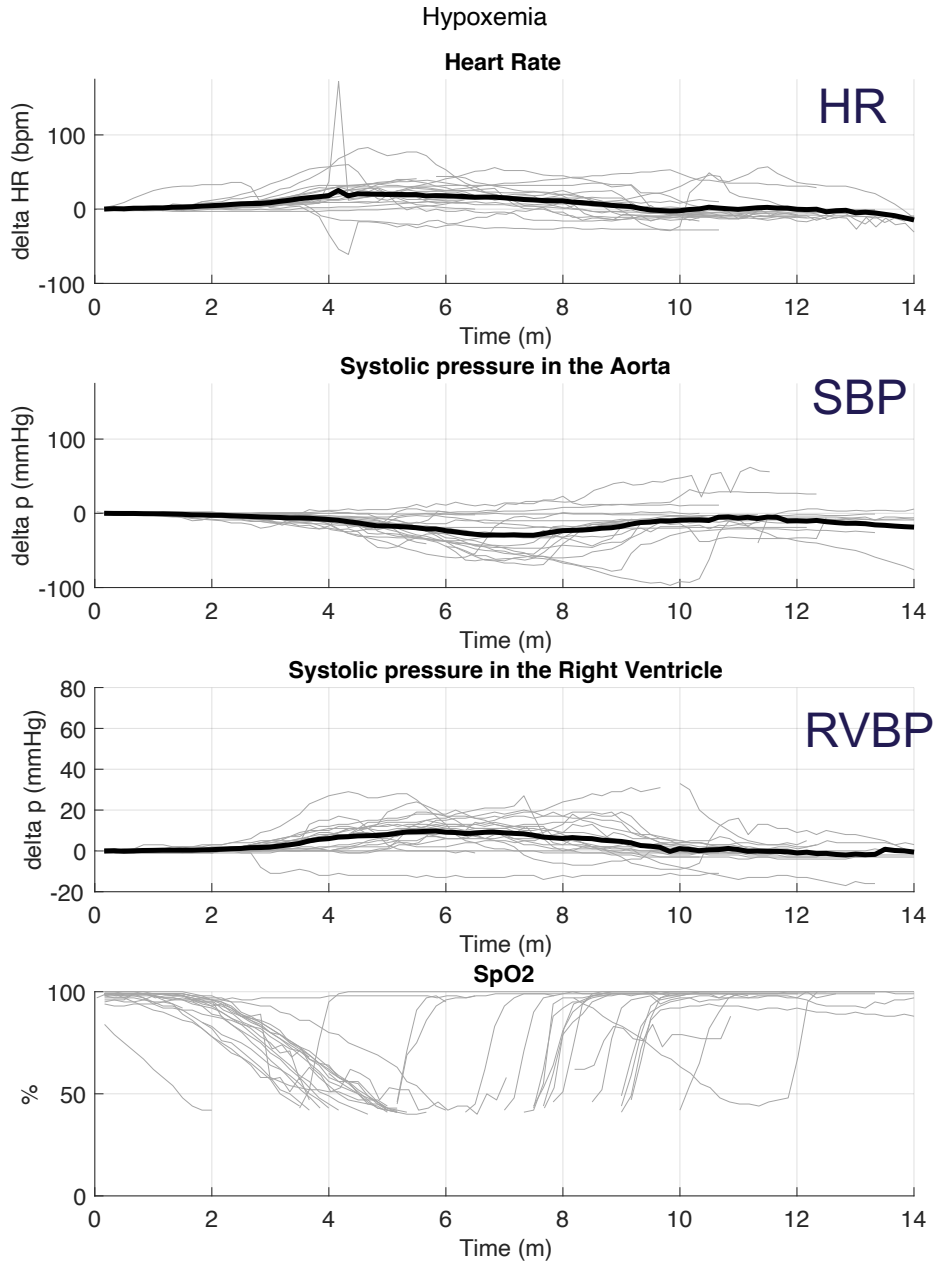


Results (Hypoxemia)
(Nitrogen inhalation)

- 7 pigs & 20 sessions
- Duration of Nitrogen inhalation: 7.5 ±2.0 minutes

	Baseline	Peak/Nadir (60 seconds)
↑ HR*	77.55±16 bpm	111.2±28 bpm
↓ SBP*	122.1±19 mmHg	82.2±21 mmHg
↑ RVBP*	30.7±11 mmHg	44.3±14 mmHg

* p<0.0001



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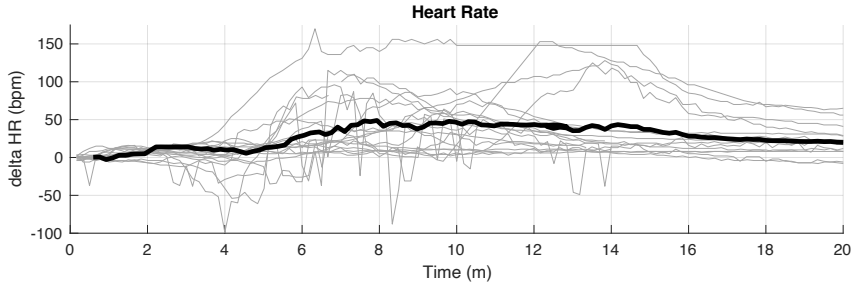
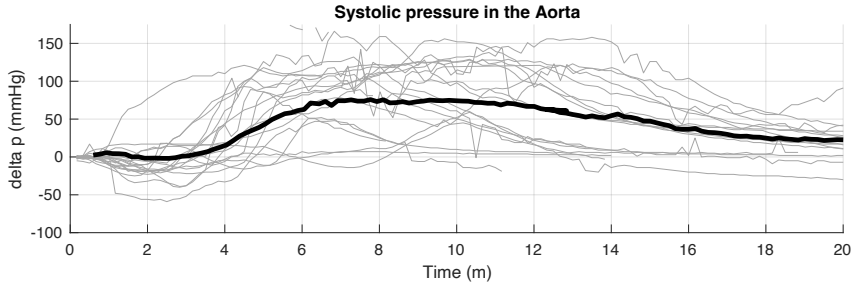
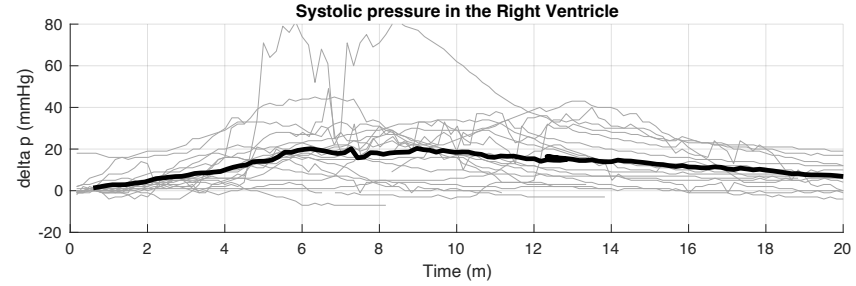
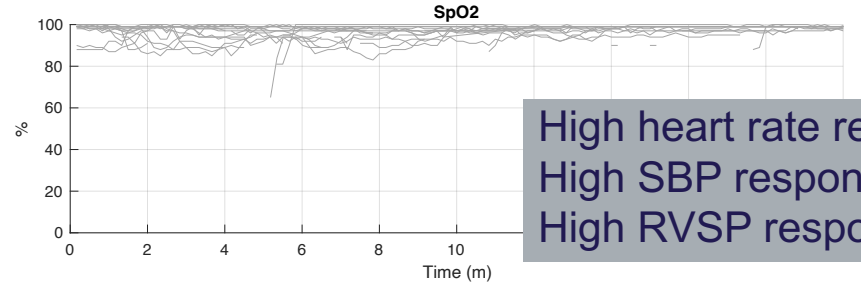
Results: Hypercapnia vs Hypoxemia

Hypercapnia



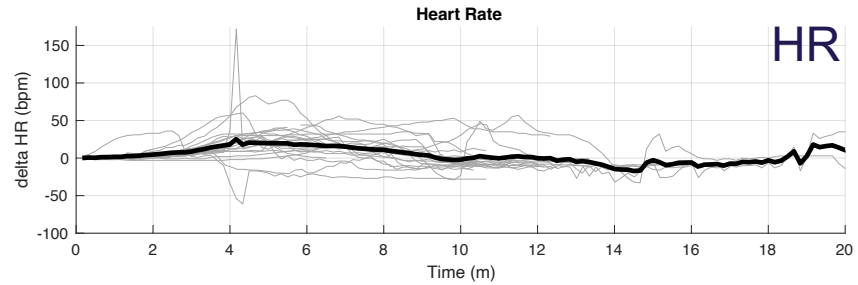




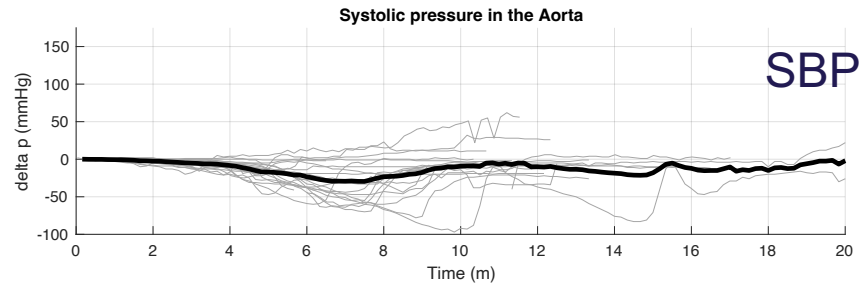


Hypoxemia

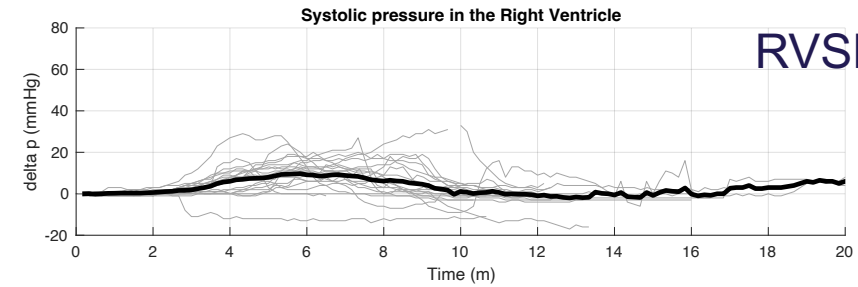
HR

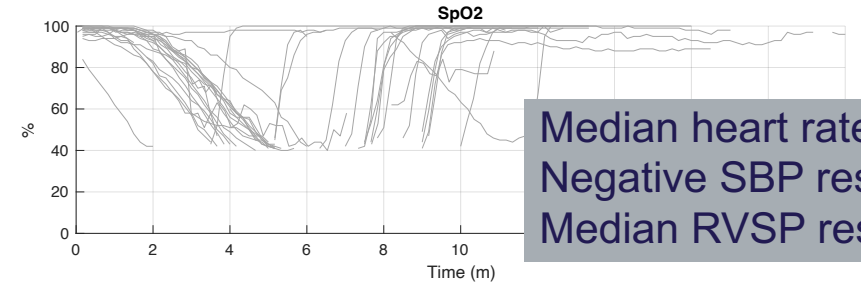


SBP



RVSP





High heart rate response
High SBP response
High RVSP response

Median heart rate response
Negative SBP response
Median RVSP response

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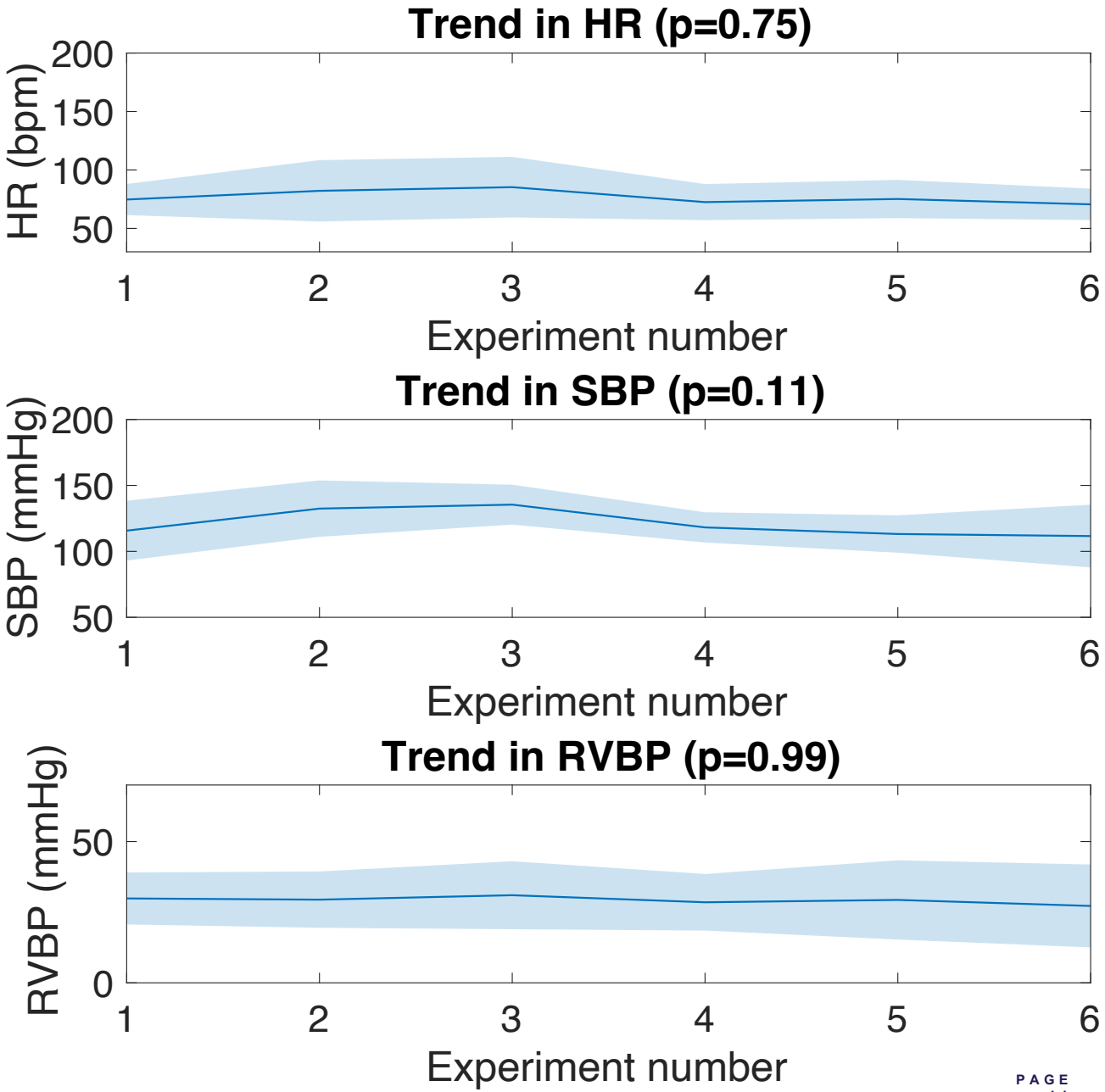
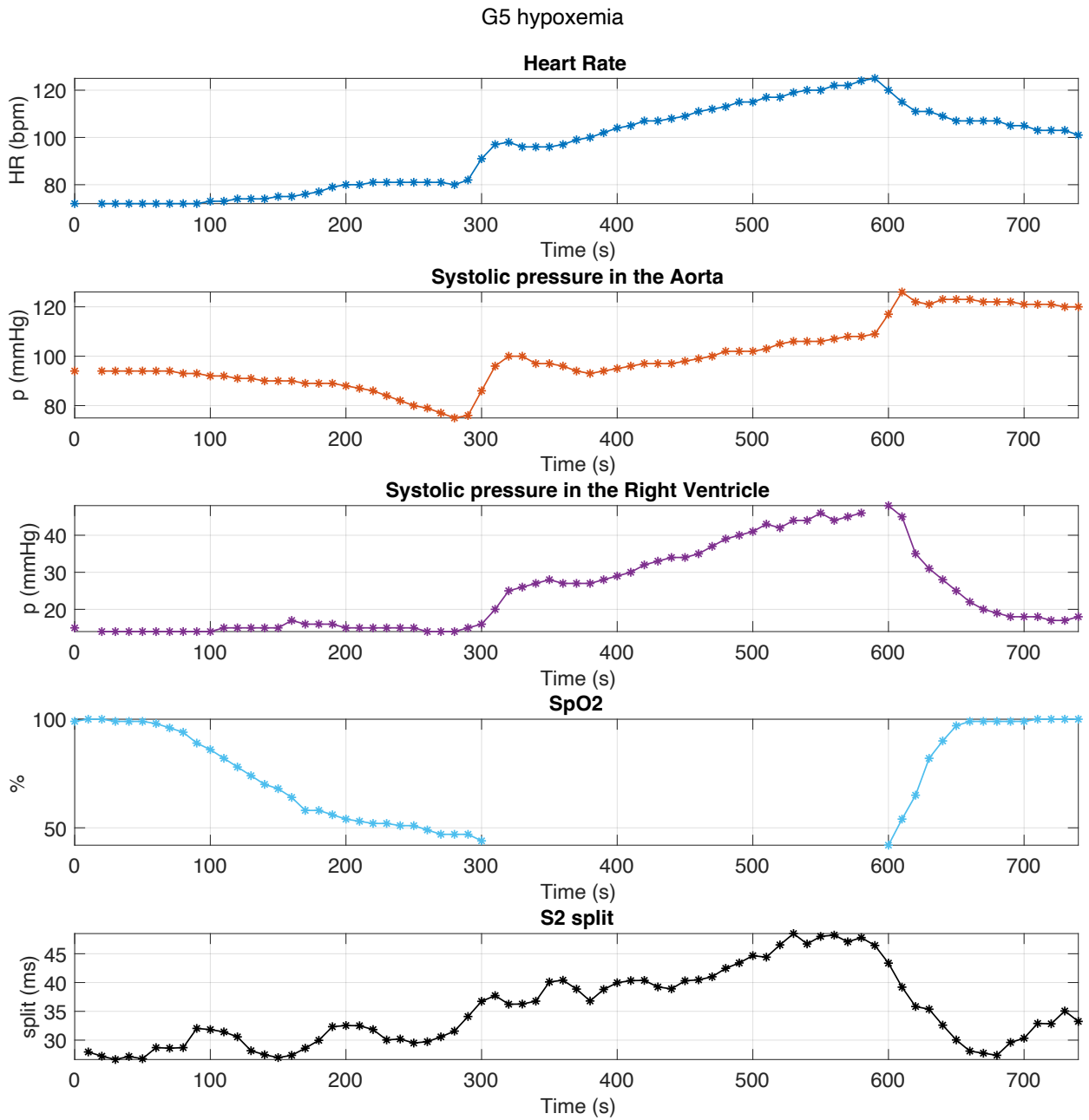
Results: Baseline values

- No trends in baseline values between repetitions
- A reversible model



Preliminary results on second heart sound (S2)

- The time split between the aorta and the pulmonary value is used as predictor of changes in PAP



Discussion:

- In the current porcine model, we was able to reversely increase the right ventricular systolic blood pressure as a proxy for pulmonary artery pressure

- Hypercapnia leads to: ↑ PAP and ↑SBP
- Hypoxemia leads to: ↑PAP and ↓SBP

- The opposing directions in systemic blood pressure allows separating the effect of PAP and SBP on the heart sounds or other estimation methods

Thank you