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# Porcine model for validation of noninvasive estimation of pulmonary artery pressure

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CardioTech  
ResearchGroup



# Study aim

- ▶ Develop a model for validation of pulmonary artery pressure (PAP) estimation methods
- ▶ Proposed 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.

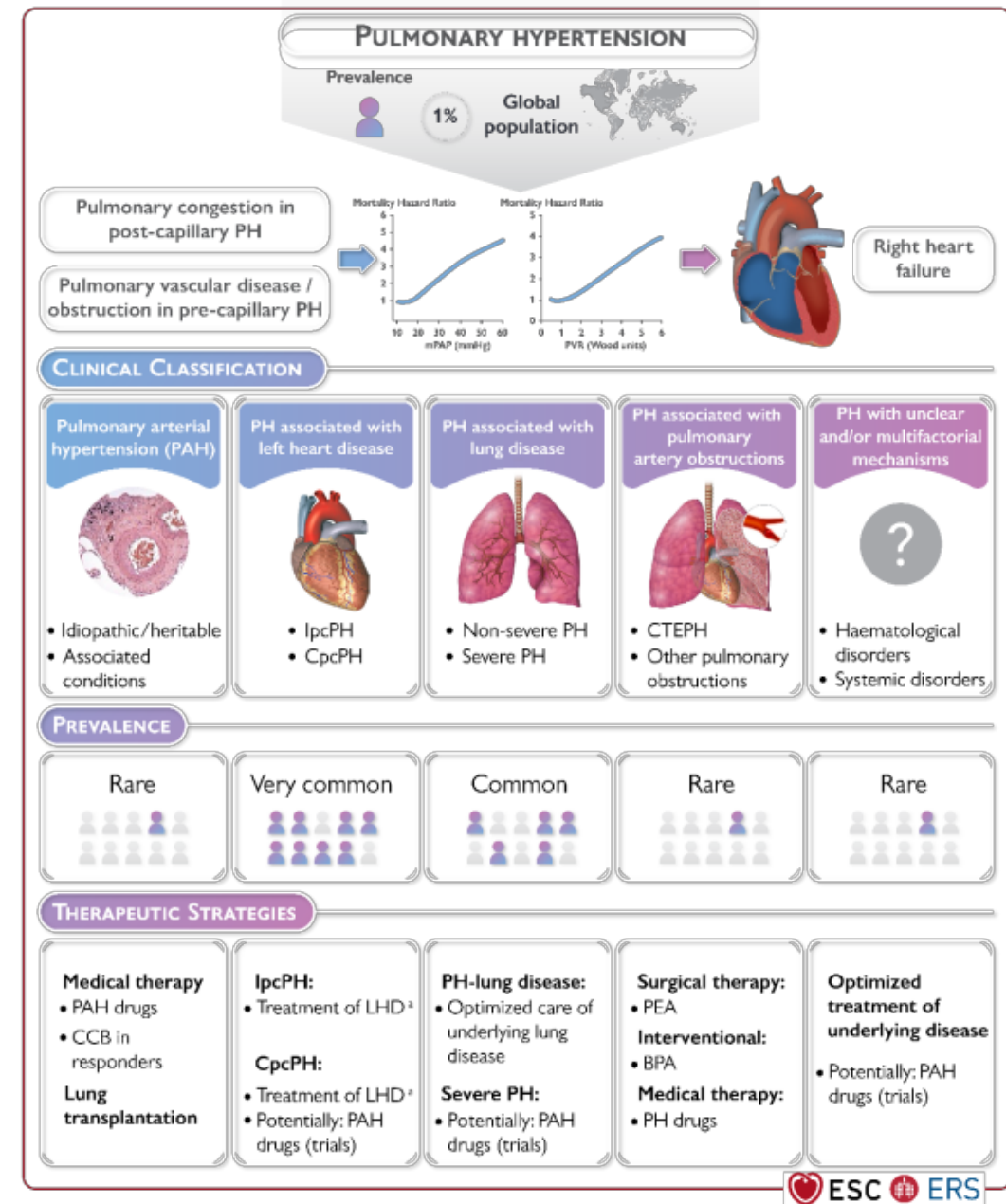
#### **SUMMARY**

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), mitral closure sound was coincident with the incisura of the pulmonary artery pressure curve

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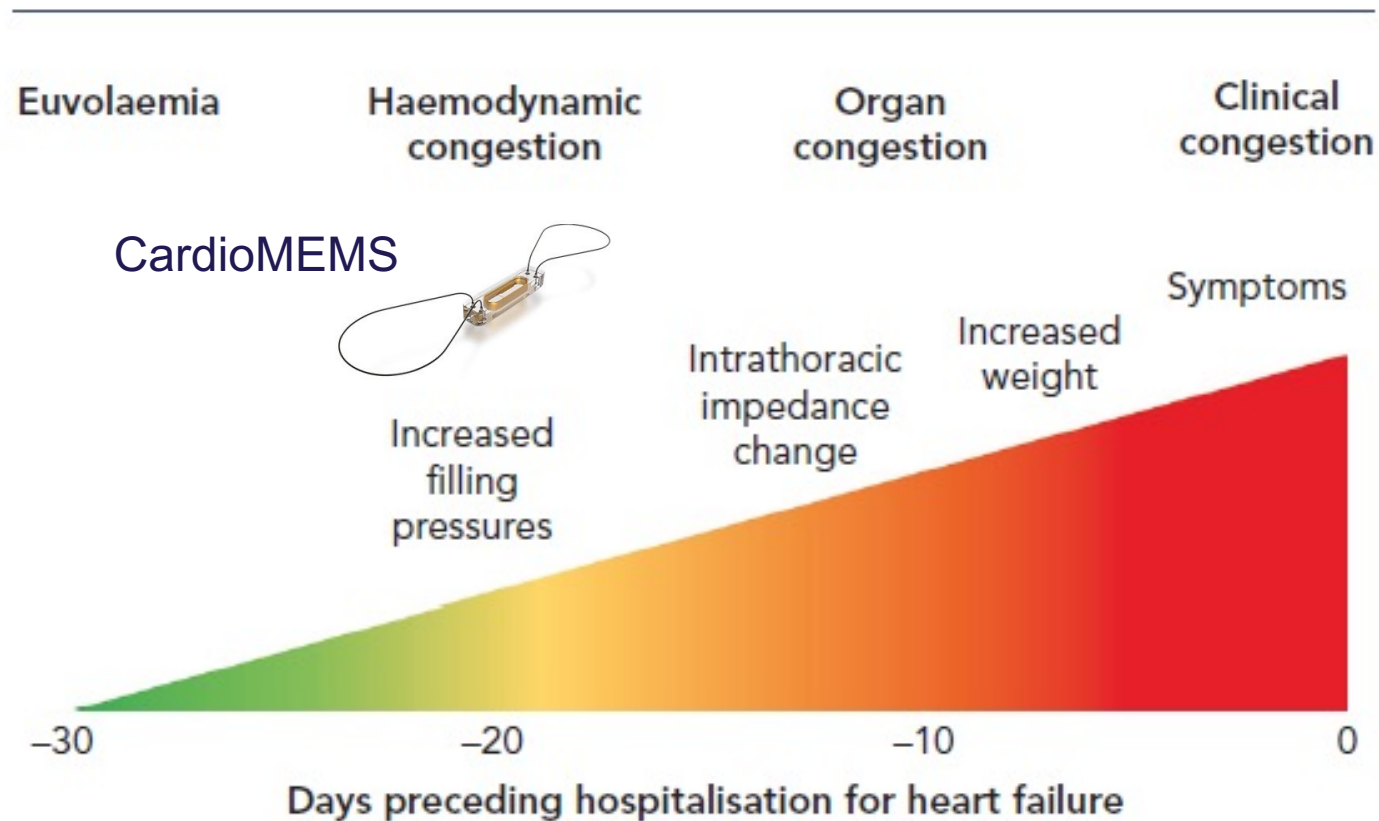
# Why measure PAP noninvasively?

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



# Why measure PAP noninvasively?

Detection of heart failure decompensation at the early stage

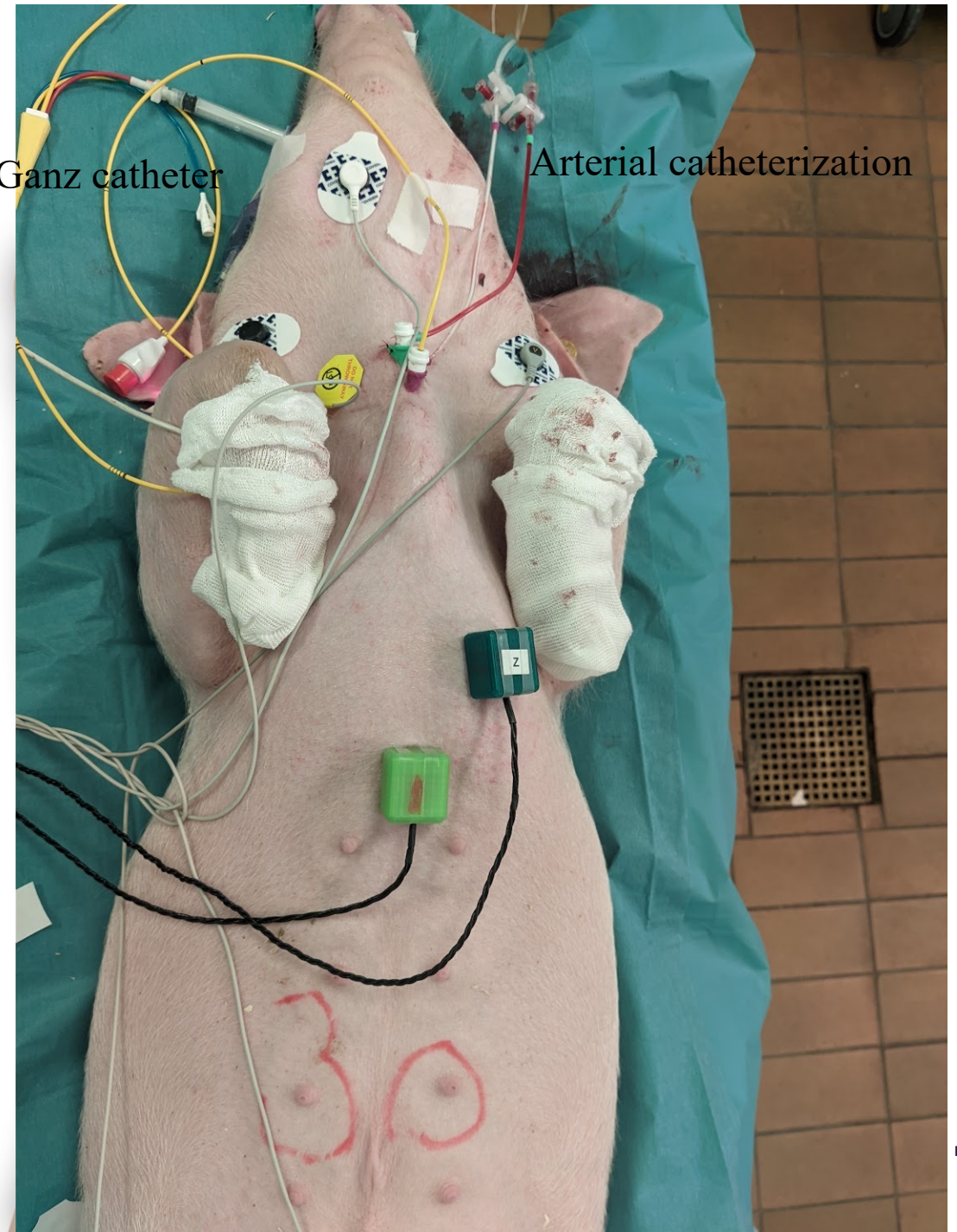


# Protocol: Set-up

- 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

Swan-Ganz catheter

Arterial catheterization

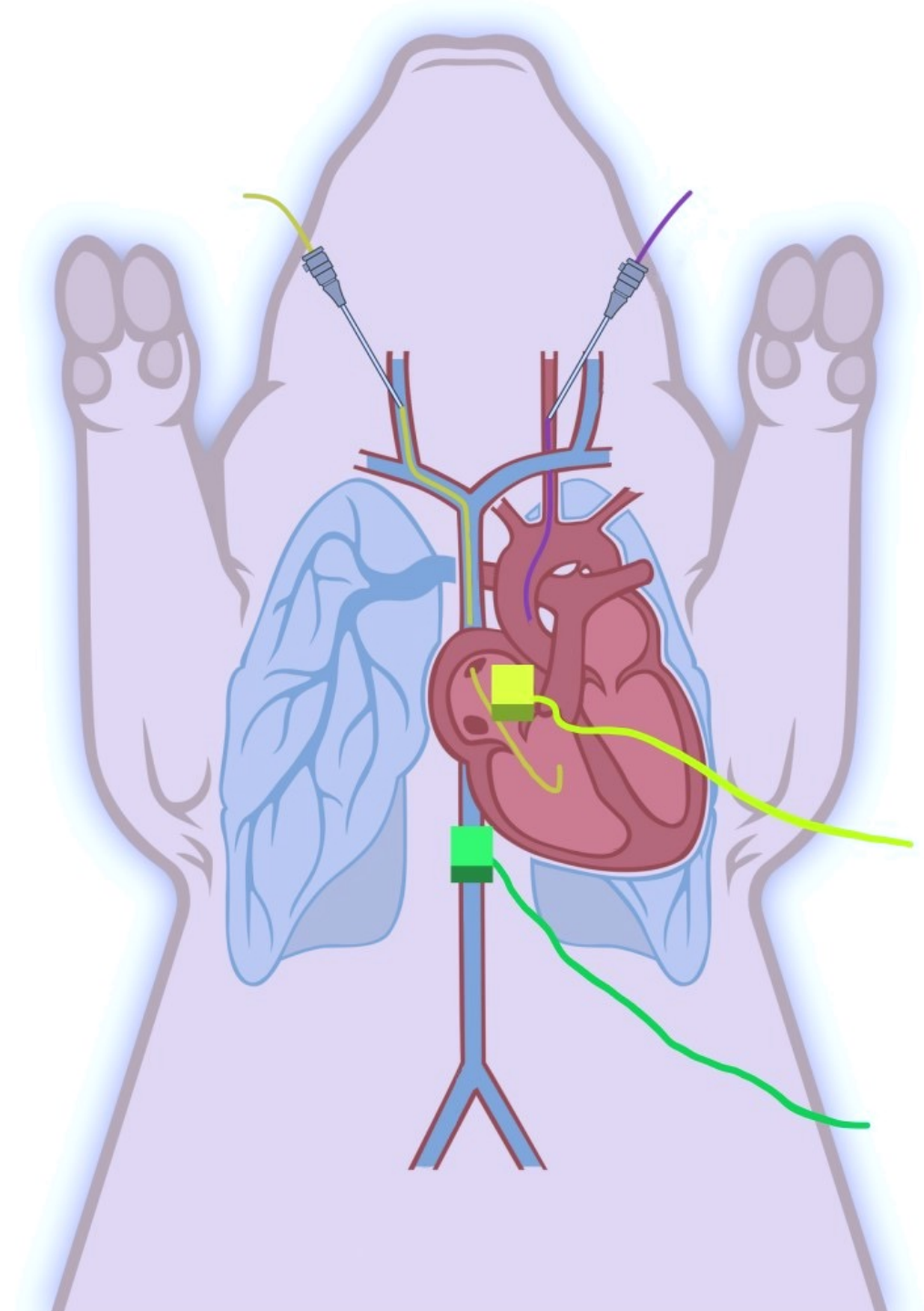




# Provocation of pulmonary hypertension (Hypoxemia)

- 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<sub>2</sub> concentration in the inspiration air leads to alveolar hypoxia that leads to pulmonary vasoconstriction

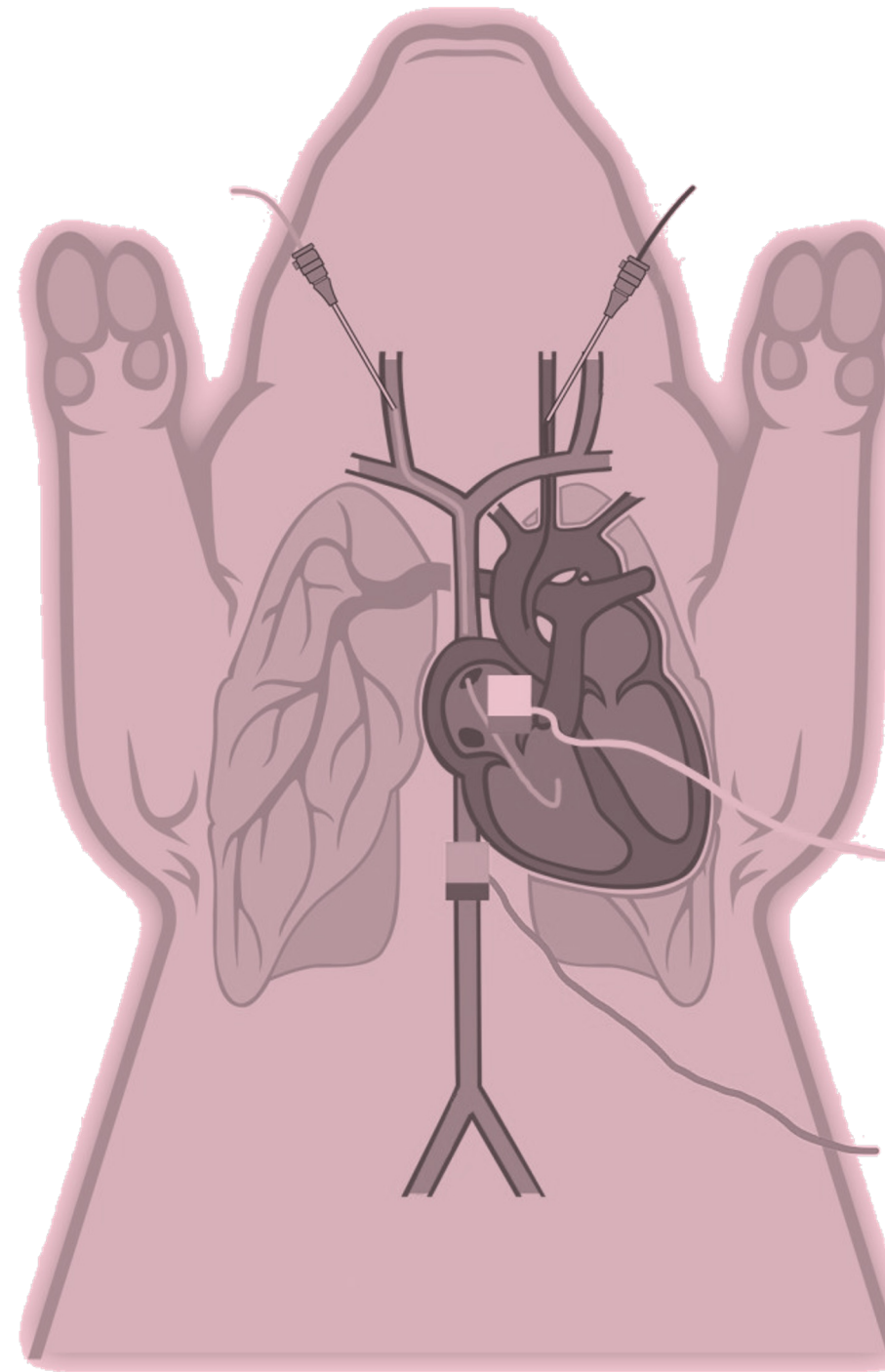
*\*D Tarry, M Powell, Hypoxic pulmonary vasoconstriction, BJA Education, Volume 17, Issue 6, June 2017*



# Provocation of pulmonary hypertension (Hypercapnia)

- Aim: Tricker pulmonary hypertension by pulmonary vasoconstriction\*
- Method: Carbon dioxide asphyxiation
  - CO<sub>2</sub> was connected to the ventilator circuit and the CO<sub>2</sub> absorber was removed from the circuit to increase the CO<sub>2</sub> concentration
  - Stopping criteria was saturation in PAP or arrhythmia
- Physiology: High CO<sub>2</sub> 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*



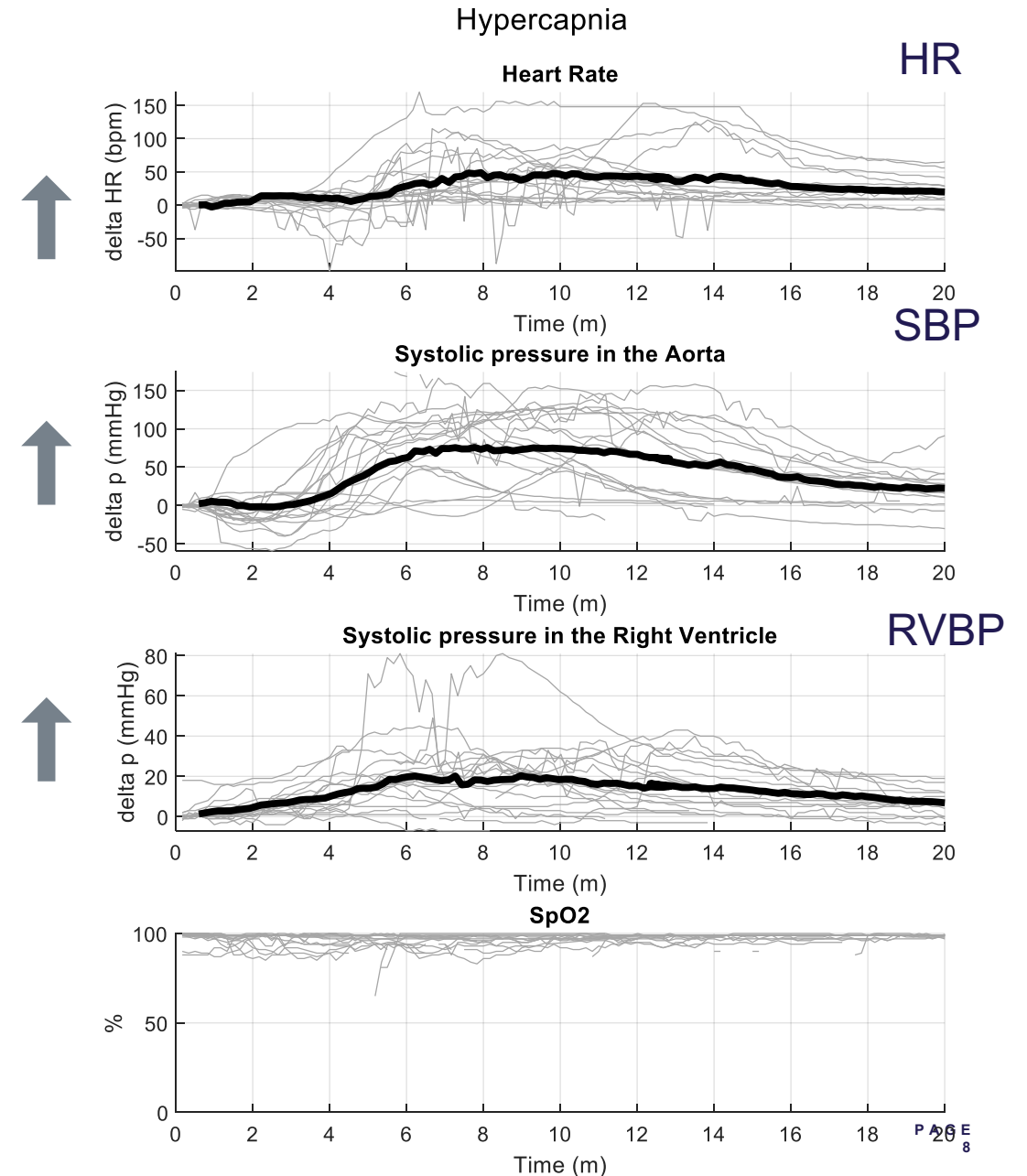


# Results: Hypercapnia (CO<sub>2</sub> inhalation)

- 7 pigs & 19 sessions
- Duration of CO<sub>2</sub> 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

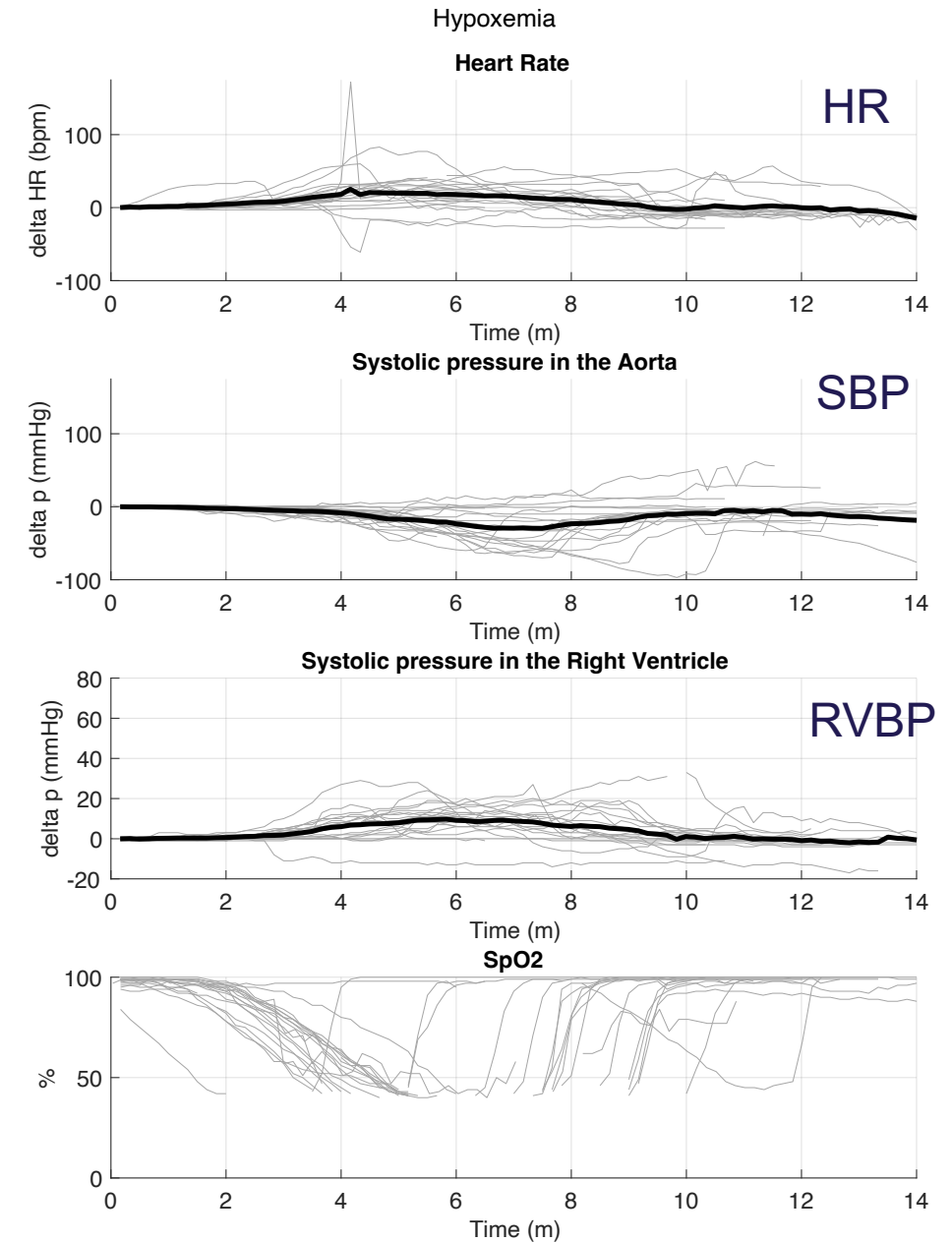


# Results (Hypoxemia) (Nitrogen inhalation)

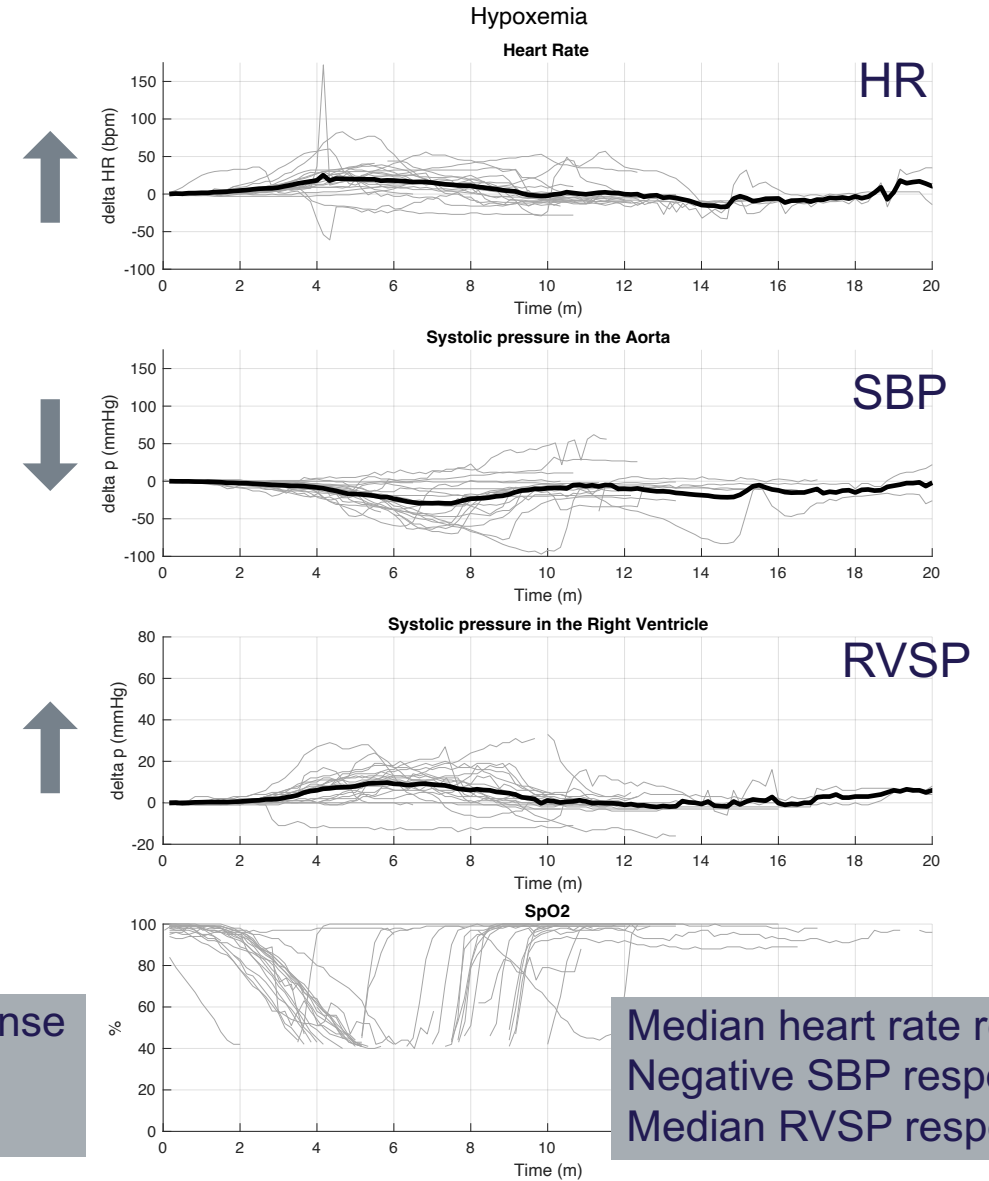
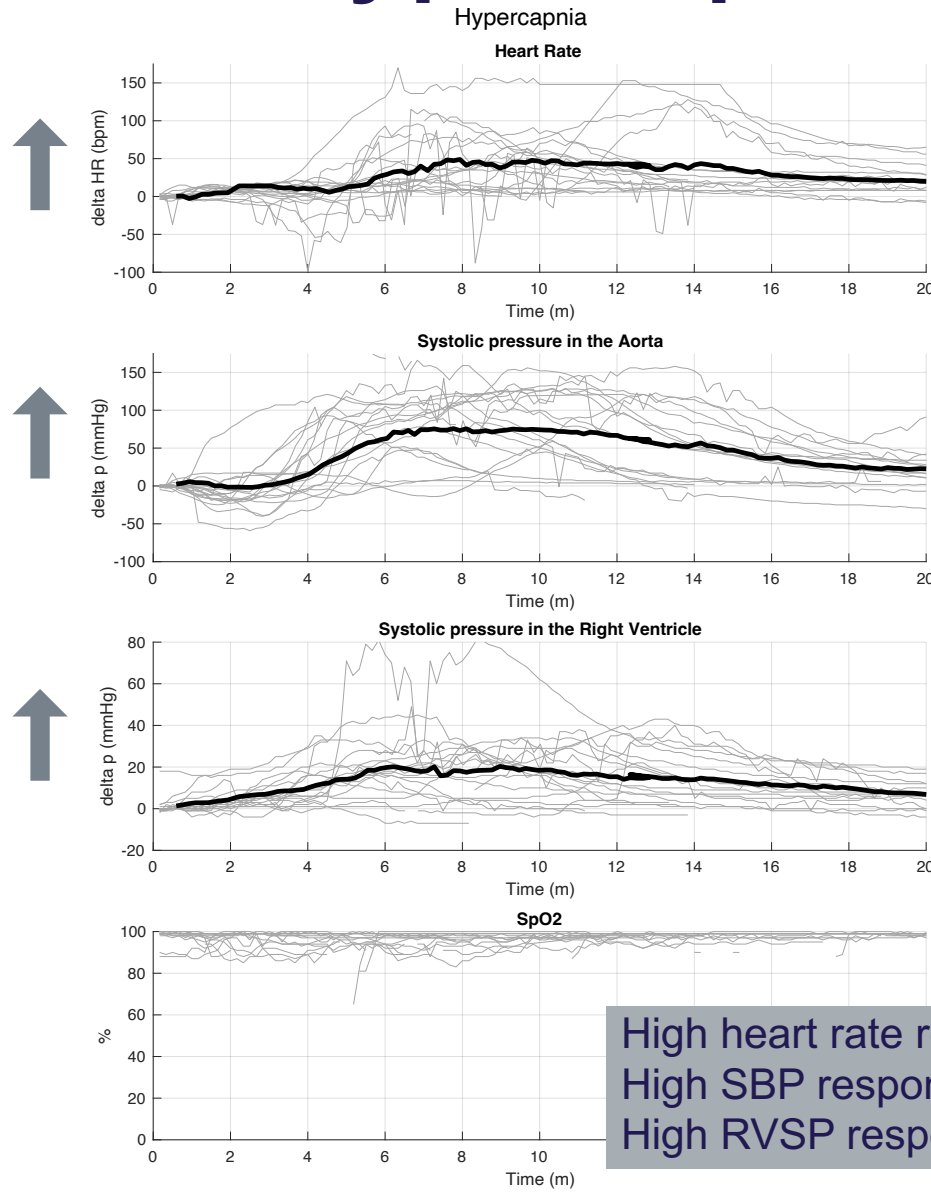
- 7 pigs & 20 sessions
- Duration of Nitrogen inhalation:  $7.5 \pm 2.0$  minutes

	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

\*  $p < 0.0001$



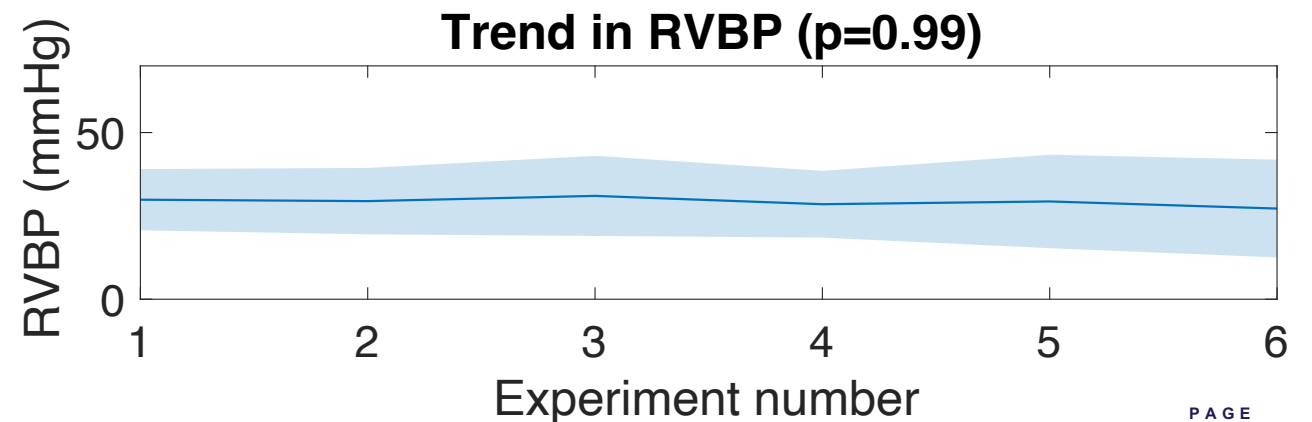
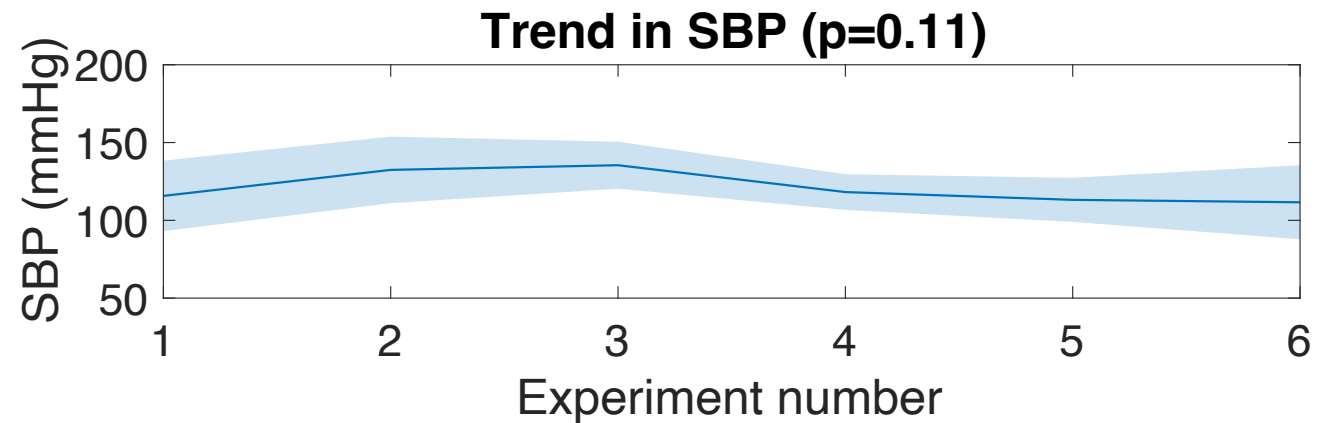
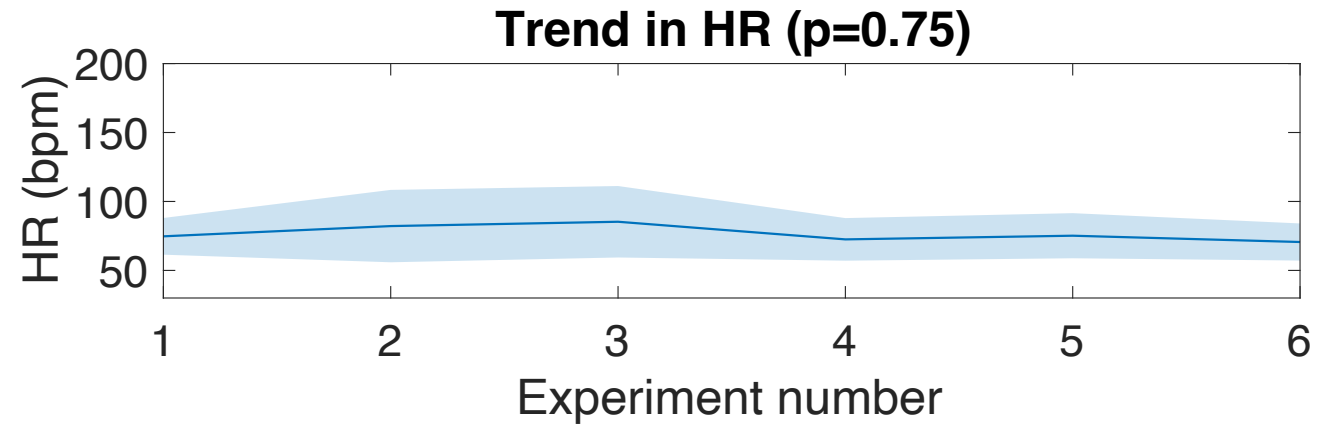
# Results: Hypercapnia vs Hypoxemia





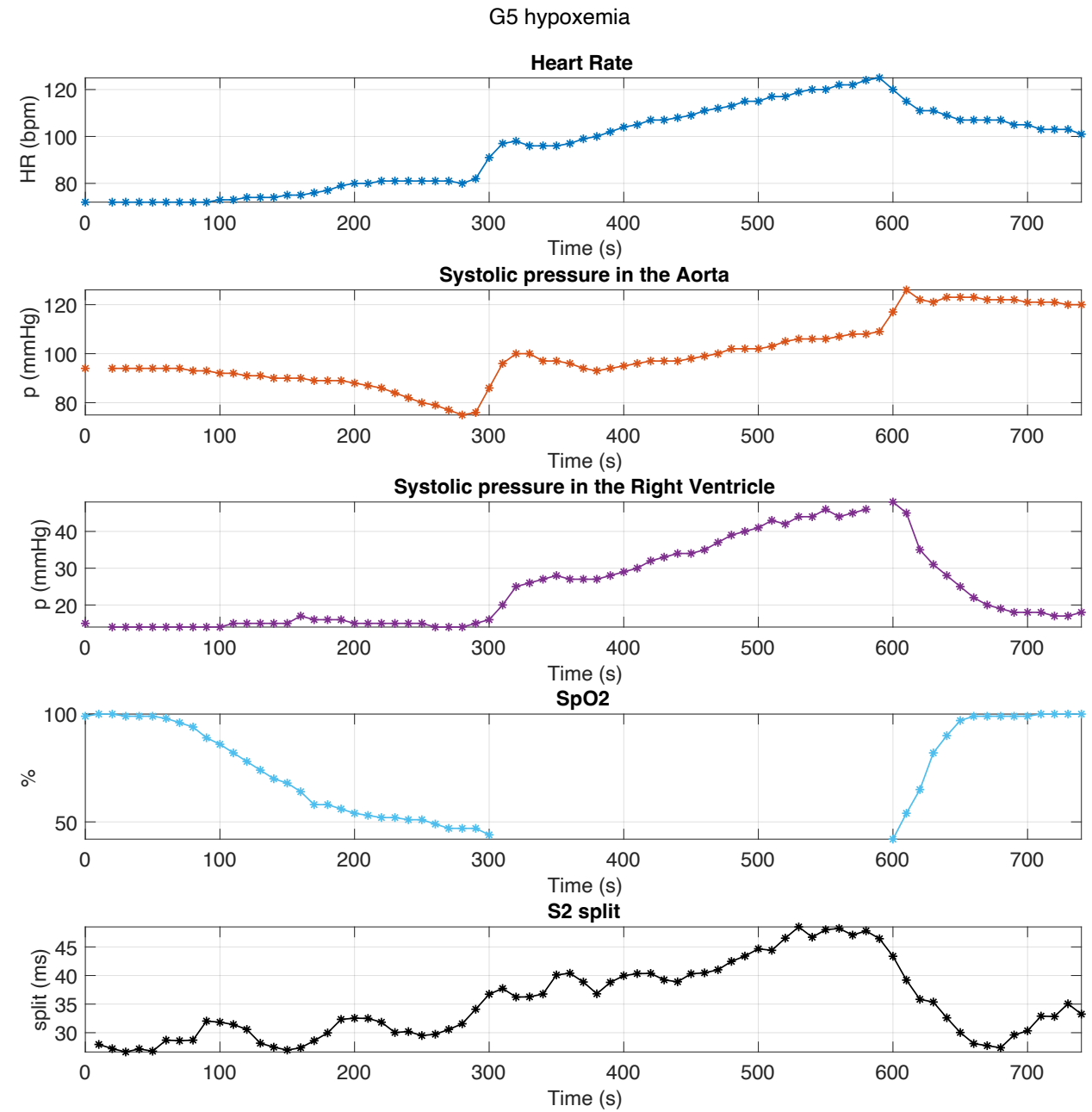
# Results: Baseline values

- ▶ 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:  $\uparrow$  PAP and  $\uparrow$ SBP
- Hypoxemia leads to:  $\uparrow$ PAP and  $\downarrow$ 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