Pulmonary arterial wall dynamics

J.M. Douwes, MD/PhD
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**SCORE: 0**
Pulmonary arterial wall dynamics

• Dynamic behavior of the arterial wall under pulsatile pressure and flow

• Goal:
  – Evaluate viscoelastic properties of the PA wall
  – Pulmonary arterial wall stiffness / compliance
Pulmonary arterial wall dynamics

- Engineering concept of material stiffness stress – strain relations
- Stiffness is an indicator of the tendency for an element to return to its original form after being subjected to a force.
Pulmonary arterial wall dynamics

Typical Pressure-Diameter Curve for Elastic Tissues

Pressure vs. Diameter graph showing:
- Elastin-dominant region
- Transition region
- Collagen-dominant region

Pulmonary arterial stiffness
Pulmonary arterial stiffness
Pulmonary arterial stiffness – animal models

• In vivo and ex vivo measurements

• Mouse model for hypoxia induced pulmonary hypertension
  – 10 days of hypoxia
  – 32 days of recovery
  – Treated with BAPN (anti-fibrotic drug)
Isolated pulmonary artery mechanical testing

Histology with collagen staining

medial and adventitial thickening with hypoxia and thinning with recovery

Pulmonary arterial wall thickness

Optically measured wall thickness at 30mmHg
- Wall thickening at hypoxia

No change in PA diameter at 5 mmHg
PA pressure – stretch relationship

PA pressure – stretch relationship

Stiffness – collagen content relation

Pulmonary arterial stiffness – animal models

- Pulmonary arterial stiffening in hypoxia induced PH
- Mediated by collagen accumulation
- Recovery effect
Pediatric PAH patient data

- Methods
  - Invasive measurements
  - Pulmonary arterial input impedance
  - Distensibility (stress-strain relationships)
  - Non-invasive measurements
Invasively measured PA compliance

Stroke volume / pulse pressure

Douwes JM, Int J Cardiol. 2013;168 (2):1370–1377
Takatsuki S. Am J Respir Crit Care Med 187;2013:A2537
Invasively measured PA compliance

Douwes JM, Int J Cardiol. 2013;168 (2):1370–1377
Takatsuki S. Am J Respir Crit Care Med 187;2013:A2537

PAC > 0.9 mL/mm Hg/m² versus < 0.9 mL/mm Hg/m²

PAC > 0.85 mL/mm Hg/m² versus < 0.85 mL/mm Hg/m²
Pulmonary arterial impedance

• “forces opposing or *impeding* flow”
• Evaluation of total RV afterload (steady and pulsatile)

• Dynamic pressure - flow relationship
• Pulsatile pressure / pulsatile flow
Pulmonary arterial impedance

Hunter KS. Am Heart J. 2008 Jan;155(1):166-74
Impedance
Impedance
Impedance
Pulmonary arterial impedance

- $Z_0 = \text{PVR}$
- $Z_c$ Higher frequencies
  - Proximal stiffness
Pulmonary arterial impedance

Hunter KS. Am Heart J. 2008 Jan;155(1):166-74
Pulmonary arterial stiffness

- Total versus local
Pulmonary arterial compliance

\[ C_{dyn} = \frac{(D_s - D_d)}{D_d \times P_s} \times 10^4 \]

Pulmonary arterial compliance

B

Relative pulmonary arterial area (%) to pressure (mmHg)

Loop compliance of systole tertiles

Number of cases:

- I: 8 3 3
- II: 8 7 4
- III: 8 3 2

Pulmonary arterial distensibility

Long term (20 year) follow-up

Pulmonary arterial distensibility

Pulse wave velocity and wave intensity analyses

Pulse wave velocity and wave intensity analyses

Future perspectives

- Animal data showing PA stiffening in PH
- Pediatric data showing prognostic value
- Not a parameter that is used in standard clinical care
Flow mediated pulmonary arterial hypertension

Feen DE. J Vis Exp. 2017; (120): 55065.
Clinical data

- More patient data
  - Large groups analyses lacking for impedance
  - Repeated measures analyses

- Improving measurement techniques
- Preferably non-invasively
To conclude

- There is PA stiffening in pulmonary hypertension
- PA stiffness is an important component of RV afterload
  - Related to disease severity
  - Predictor of outcome
  - Early predictor of outcome
  - May help in decisions on operability of CHD

- However
  - We need more data!
Thank you.
High altitude calf model