Mechanical properties of porcine coronary arteries : what is the in vivo axial strain?

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Introduction

Knowledge of mechanical properties of living arteries is important to understand vascular function during health and disease. An effective way to study the behavior of living tissue is organ culture.

In arterial culture the artery should be loaded at in vivo levels to maintain the artery's viability. The in vivo axial strain of coronary arteries, however, is unknown. Therefore, the aim of this study is to determine the physiological axial strain of the porcine left anterior coronary artery (LAD, fig. 1a). Based on [1] it is hypothesized that:

The in vivo axial strain of an artery is the strain at which the axial force is relatively insensitive to changes in pressure.

This strain, as shown in fig. 1b, will be determined for the porcine LAD in an organ culture model. The hypothesis will be validated in an isolated beating heart experiment in which a porcine heart is loaded physiologically. Due to the pumping of the heart, a cyclic axial strain is induced to the coronaries.

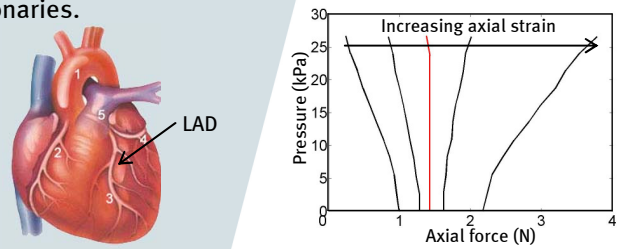

Figure 1 a) LAD on heart; **b)** Axial force-pressure measurement of a rat carotid artery [1]. The hypothesized pressure-axial force response of an artery at physiological strain is given in red

Material and methods

Culture model experiment (CME)

- Excision of segment of porcine LAD
- Length measurement of:
  - Segment still connected to the heart (l_{heart}, fig. 2)
  - Segment at its ex vivo (unstrained) length (l_{ev}, fig. 2)
- Cyclic pressure loading of segment in culture model (fig. 3)
- Stepwise increase of axial strain until the physiological length of the segment is found (l_{phys}, fig. 2)

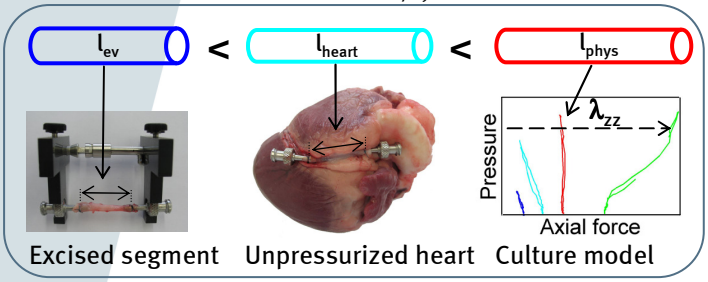

Figure 2 Definition of different segment lengths determined in culture model experiment

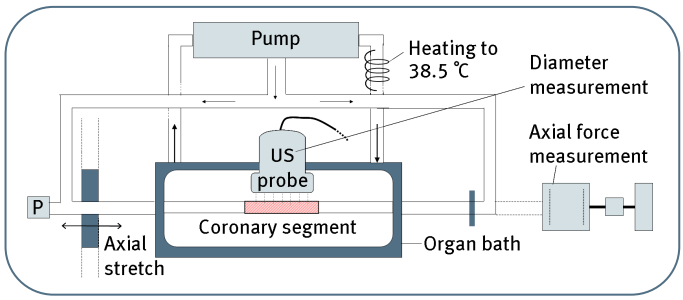

Figure 3 Porcine coronary artery culture model.

Isolated porcine heart experiment (IPHE)

- Isolated beating porcine heart (HemoLab)
- Markers in parallel to LAD (fig. 4)
- High speed camera recording of the LAD ex vivo strain amplitude during a heartbeat
- Dissection of marked segment to determine l_{heart} and l_{ev}

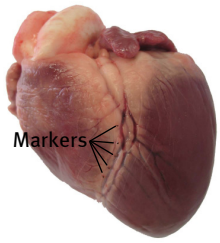

Figure 4 Markers on heart for IPHE

Results

- CME: Small spread in different axial strains (fig. 5a)
- IPHE: Preliminary results as N=1

  λ_{heart}=1.2, $\lambda_{phys,min}$=1.3, $\lambda_{phys,max}$=1.38 (fig. 5b)

  Length change during a heart beat is 0.08 of l_{ev}

The physiological stretch derived from the CME equals the maximum stretch of an artery during a heart beat (IPHE).

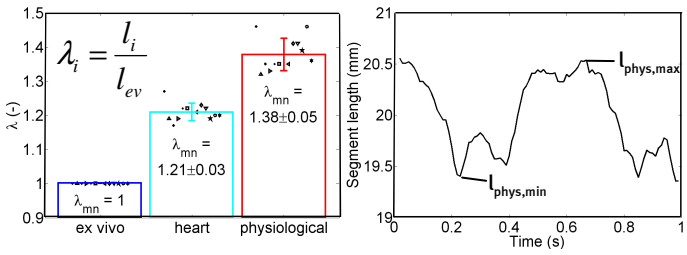

Figure 5 a) Axial stretches derived from the CME (N=12); **b)** Segment length during 1 heart beat in IPHE (l_{ev} =14.9 mm, N=1)

Conclusions

The physiological axial strain can indeed be defined as the strain of an artery at which the axial force is relatively insensitive to changes in pressure. The average axial stretch of the porcine LAD is 1.38±0.05, which is the maximum stretch during a heart beat. More isolated beating porcine heart experiments need to be conducted to be conclusive.

References:

[1] Weizsäcker, H.W. *et al.* (1983) J. Biomechanics, **16**, p703-715