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Strain transfer through the aortic valve and its relevance to the cellular mechanical environment

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Objectives:

Valve interstitial cells respond to local tissue strains through mechanotransduction pathways, altering cellular stiffness and collagen biosynthesis. Manipulating cell strains can optimise this response. However, this requires knowledge of physiologically representative strains experienced by interstitial cells in situ. The complex hierarchy of connective tissues means cell strains cannot be directly derived from applied strains. This study investigates strain transfer through the valve matrix, hypothesising that cell strains will be smaller than applied tissue strains.

Method:

Radial and circumferential dumbbells were cut from aortic valve leaflets and strained to failure (quasi-static: 60%.min⁻¹) obtaining stress-strain curves (n=12). Further radial and circumferential samples (n=5) were incubated in 5 mM Acridine Orange to stain the cell nuclei, loaded into a rig on a confocal microscope stage and incrementally strained in 2.5% increments to 40%. Nuclei were imaged at each increment and their location used to calculate the local strain at each increment.

Results:

Failure stress was 8x greater in the circumferential direction, whilst failure strain was 2x greater in the radial orientation. From microscopy, local strains were consistently smaller than applied strains in both orientations. However, whilst local radial strains were consistently around 60% of applied values, local circumferential strains were only 20-30% of applied values, with a non-linear relationship between applied and local strains.

Conclusions:

Results demonstrate strain transfer through the matrix is not direct: radially strain is transferred linearly to cells, whereas circumferentially cells are shielded. This shielding may result from matrix re-organisation, and may be important for preventing cellular damage during normal valve function.