THE AUTOMATED CHARACTERISATION OF COLLAGEN FIBRE ORIENTATION IN ARTERIES USING SMALL ANGLE LIGHT SCATTERING

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Introduction

Arteries are fibre-reinforced vessels whereby collagen fibres provide structural strength to the vessel wall. Disease induced maladaptive remodelling can alter the alignment of these fibres and consequently the strength of the vessels. A greater understanding of the remodelling of these fibres may provide greater insight into arteries at risk of disease and how arterial repair may be induced.

Small angle light scattering (SALS) has previously been used in the characterisation of thin, highly organised tissue structures, such as bovine pericardium and porcine aortic valve tissue [1].

The aim of the present study is to design and develop a SALS device capable of the automated characterisation of the collagen fibre architecture within arteries.

Materials and Methods

An in-house SALS system has been developed which incorporates an unpolarised 5mW HeNe laser (λ = 633nm) and two focusing lenses to pass light through a tissue sample held in custom-made grips. The resulting scattered light pattern is recorded by a CCD camera and analysed to determine predominant collagen fibre directions. To validate the system, testing was conducted on (i) an artificial electrospun fibre sample stretched along a single axis to vertically align the constituent fibres, (ii) an aortic valve leaflet and (iii) sectioned aortic wall tissue, which was processed using a standard histological tissue processing protocol.

Results and Discussion

SALS images obtained from the electrospun sample post-stretch demonstrated vertical alignment of the fibres within the sample and this was supported by light microscopy.

Orientation results obtained via SALS throughout the porcine aortic valve tissue sample were in-line with those obtained in the literature [2]. Finally, SALS results from sectioned porcine aorta samples showed a predominantly vertical scattering of light (Fig. 1), suggesting the circumferential orientation of the collagen fibres in the vessel wall. These results are in line with previous work on healthy arterial tissues whereby collagen fibres have been found to be predominantly orientated circumferentially in the arterial wall so as to offer the greatest structural support to a vessel [3].

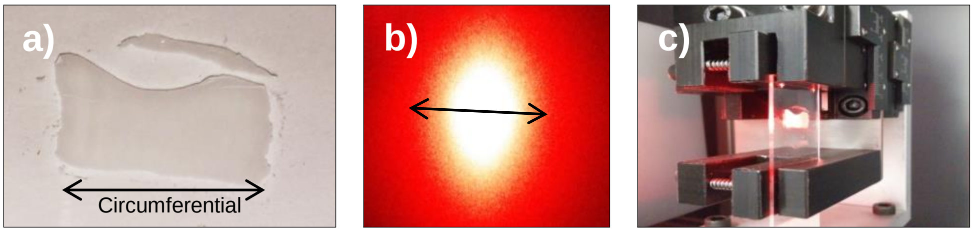

Fig. 1: a) Sectioned porcine aortic wall tissue, b) Porcine aortic wall SALS pattern showing indicative fibre angle, c) Tissue during testing

Conclusions

Preliminary results indicate that SALS may be a viable method for determining the orientation of collagen fibres within arterial tissue. Future work will focus on enabling collagen fibre patterns to be ascertained in real-time during dynamic testing of tissue, with a view to further elucidating the mechanism of the collagen fibre remodeling process in vascular tissues. This work will support the development of more accurate collagen fibre remodeling algorithms and thereby enable the development of improved *in silico* models for the prediction of fibre remodeling in patient specific arteries.

References

1. Billiar, K., and Sacks, M., J. Biomech. 30: 753–756, 1997
2. Sacks, M. S., Smith, D. B., and Hiester, E. D., Ann. Biomed. Eng. 25: 678–89, 1997.
3. O'Connell et al., Matrix Biol. 27: 171–81, 2008.

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