A novel protocol to characterise the mechanical properties of spinal cord tissue and benchmark candidate biomaterials for CNS tissue-engineering

RD Bartlett¹ 2, D Choi², JB Phillips¹

¹ Biomaterials & Tissue Engineering, UCL Eastman Dental Institute, UCL, England. ² Brain Repair & Rehabilitation, Institute of Neurology, UCL, England

INTRODUCTION: A number of tissue-engineered approaches are currently in development to promote repair in the injured spinal cord. In addition, it is widely regarded that the mechanical properties of a tissue have the potential to profoundly affect cell behaviour [1]. As such, to promote optimal cell growth and host-tissue integration in the CNS, biomaterial candidates will need to be designed with the biomechanical properties of spinal cord tissue in mind. Nevertheless, given the viscoelastic nature of cord tissue, accurate mechanical characterisation has so far been difficult. Thus, the aim of this project was to develop a reliable testing protocol able to probe the mechanical properties of spinal cord tissue, and one which might ultimately be used to mechanically screen biomaterials for CNS tissue-engineering applications.

METHODS: Wistar rats (male) weighing between 380 – 480 g were culled and spinal cords displaced using a fluid-filled syringe. These were then immediately placed in AQIX RS-I (Liquid Life) tissue-preservation media ready for mechanical testing.

Cord sections were then cut to approximately 5 mm in length, and height measurements for each section taken using a contact angle machine. A mean height for each specific section was then calculated, and this used to generate a 0.5 % dynamic strain. Sections were then placed in a Dynamic Mechanical Analysis (DMA) system (Bose Electroforce 3200), where they were subjected to an ascending frequency sweep of 1 – 100 Hz. To test for destructive changes, a 1 Hz validation frequency was repeated after the full frequency sweep had been completed. Pre- and post-DMA sample volumes were also measured as a means of geometric validation. Sections were kept on ice until the point of geometric measurement, however, they were allowed to equilibrate to room temperature before mechanical testing began. All samples were maintained at 100 % humidity throughout.

RESULTS: DMA testing revealed that rat spinal cord compression modulus was in the range of 1 – 10 kPa. This was found to be a strain-rate dependent phenomenon, whereby tissue stiffness increased non-linearly with frequency. We also found that DMA testing caused a small (< 1 kPa) change in the 1 Hz validation frequency.

DISCUSSION & CONCLUSIONS: Values obtained for rat spinal cord compression modulus were in accordance with previously published literature [2]. Yet, in contrast to other mechanical characterisation techniques available, our protocol was able to elucidate the range of modulus values seen in spinal cord tissue over its viscoelastic range. If future tissue-engineered therapies are to be successful, it is likely that careful consideration must be given to the biomechanical properties of native spinal cord tissue. Our novel testing protocol offers one such way in which promising new biomaterial candidates could be easily tested and benchmarked against endogenous cord tissue, and we anticipate that it may add a useful new addition to the CNS tissue-engineers toolbox.


ACKNOWLEDGEMENTS: This research was kindly funded by contributors to the UCL MBPhD Programme.

Fig. 1: Compound modulus values (E*) of rat spinal cord using an ascending sweep of 1 – 100 Hz. Error bars depict ± 1 SEM (n = 4).