Measurement of pressure-expansion behaviour required in infant airway stents using digital image correlation (DIC) in rabbit trachea

Isaiah Adekanmbi[1], K.E. Tanner[1], Haytham Kubba[2]

[1]Biomedical Engineering, School of Engineering, University of Glasgow, Glasgow, G12 8QQ, UK
[2]ENT Paediatric Surgery, Royal Hospital for Children, Glasgow, G51 4TF, UK

Mechanics and Modelling in Biomaterials Science and Engineering - Mechanical properties of Biomaterials

INTRODUCTION Airway stents are used during treatment of tracheal deformities in infants. However, complications including post implantation stent migration occur [1], resulting from too low stent radial stiffness, which causes permanent stent collapse. This collapse is partially controlled by the mechanical properties of the trachea. However, the mechanical behaviour of the human trachea is poorly understood [2]. A clearer understanding of this relationship should improve the long term performance of infant airway stents. Rabbit tracheas provide an appropriate model for neonates due to the similarities in size and shape [3]. Digital image correlation **(**DIC) compares the displacement of a random speckled pattern on the surface of a sample before and during deformation to compute mechanical strains [5]. The aim of this study was to determine the pressure-expansion characteristics of full length rabbit trachea using DIC and thereby predict the required mechanical properties for an infant airway stent.

Materials and Methods *Specimen preparation:* Tracheas from New Zealand White rabbits (lengths 42.1±5.3mm, n=20), aged 13-16 weeks were dissected within 3hrs of sacrifice and immediately immersed in phosphate buffered saline and frozen. Prior to testing, samples were thawed and a random speckled pattern was produced on the surface of the trachea (Fig1A) using black ink (Higgins Black Magic, Water Proof Ink) superimposed on a white background (SupaDec Spray Paint). A balloon dilatation catheter (Ultrathin Diamond, Boston Scientific) connected to an inflation pump (Basix COMPAK Inflation syringe) was inserted through the tracheal cavity.

DIC and loading regime: A Vic3D digital image correlation device (Rutherford Appleton Laboratory – really?? This is the supplier NOT the manufacturer) was used to record displacement vectors during tracheal expansion. Two high resolution cameras mounted onto a tripod were positioned so that the frontal surface of the trachea was visible to both cameras simultaneously, allowing 3D surface strain measurements. The balloon pressure was increased in increments of 0.2 atm (20kPa) while tracheal expansion was recorded.

Results Axial/longitudinal strain (ε_{xx}) for applied pressures of 0.2-1.0 atm increased from 0.0053- 0.01115 (Fig1b). DIC showed that deformation of the trachea by balloon dilatation was characterised by uneven expansion with higher Axial/longitudinal strain (ε_{yy}) occurring distal to the balloon compared with the central zone of the trachea (Fig2). The tracheal expansion modulus at low strains was calculated to be 9.08MPa.

Conclusions the DIC technique has the potential to provide accurate assessment of infant airway mechanics and prediction of pressure expansion properties required in paediatric tracheal stents.

REFERENCES

1. Chin, CS., et al., (2008) *Ann Thorac Surg* **85**, 792–6
2. Trabelsi, O., et al., (2010) *Med Eng & Phys* **32 ,**76–82
3. M.S. Loewen, D.L. Walner (2001) *Lab Animals* **35**, 253-256.
4. Verhulp, E., et al., (2004) *J Biomech* 37, 1313–1320

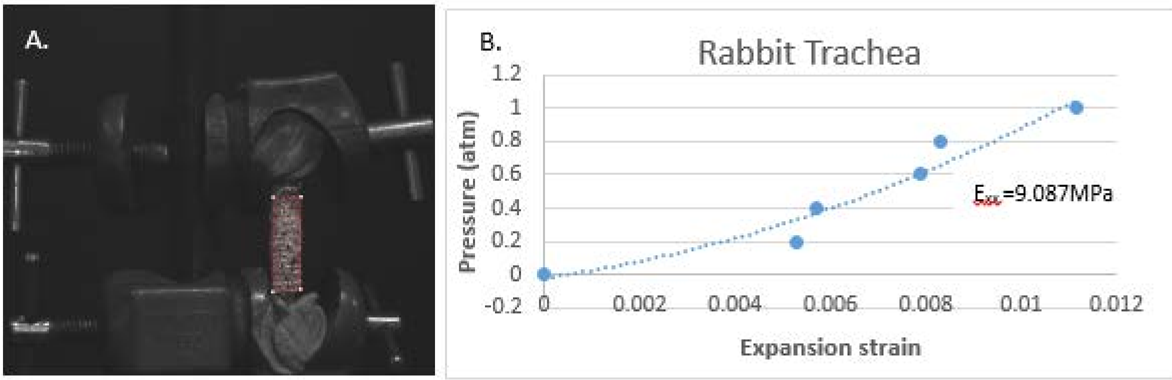

Figure 1: a.) Mechanical test set up showing trachea sample between clamp grips. A random speckled pattern of black dots was produced on the sample surface and the highlighted area of interest (AOI) is indicated by the red rectangle b.) Pressure-expansion strain (ε_{xx}) relationship measured in full length trachea. 1atm: 101.3kPa conversion was used to calculate the maximum Expansion modulus (E_{xx})

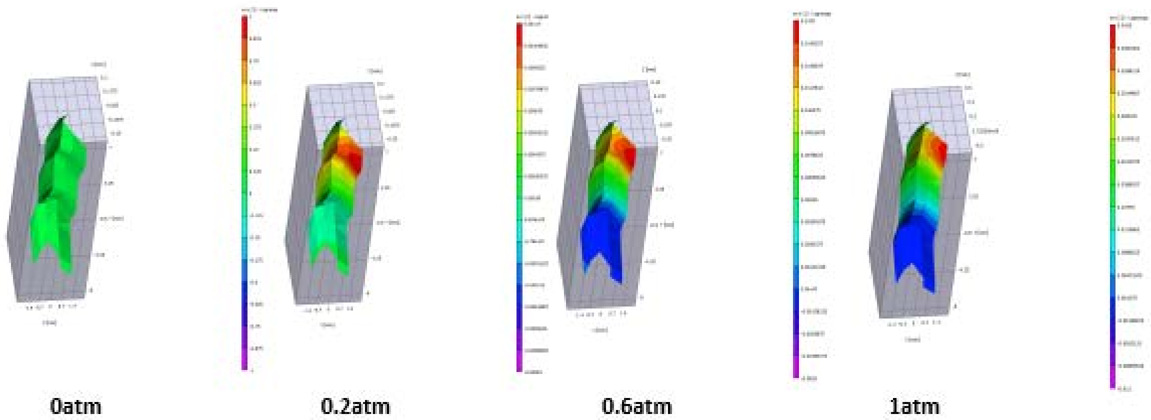

Figure 2: Strain map during pressure expansion of rabbit trachea showing heterogenous (longitudinal, ε_{yy}) deformation of sample