Measuring the internal geometry of an anastomosed synthetic blood vessel under internal pressure

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Introduction

The surgical procedure of joining two arteries, or an artery and synthetic graft together (arterial anastomosis) using sutures (stitches) is now a common practice for vascular diseases as well as other reconstructive surgeries. Many complications can arise post-surgery, hence highlighting the importance of understanding end-to-end anastomoses.

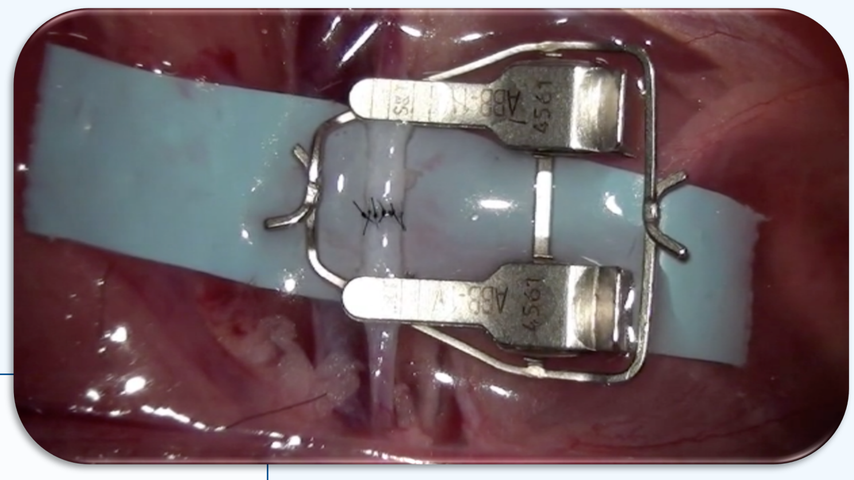


Figure 1 – Image of surgical anastomosis (Image courtesy of Sandra Shurey)

Aims

- Verify the geometry of a synthetic representation of an artery under pressure

Objectives

- Design and build a rig to apply pressure to a synthetic representation of an anastomosed artery
- Measure how geometry varies as a function of varying internal pressure and axial pretension
- Compare with theoretical predictions how geometry varies as a function of pressure

Method

A rig was designed to apply pressurised fluid to an anastomosed representation of an artery.
The changes in diameter and length were measured using two methods:

CT Scanner method (in collaboration with Derriford Hospital CT Unit)

- CT scan the specimen at each pressure and take measurements.

Optical Method

- Take a picture of specimen at each pressure and measure using Image-J analysis software.

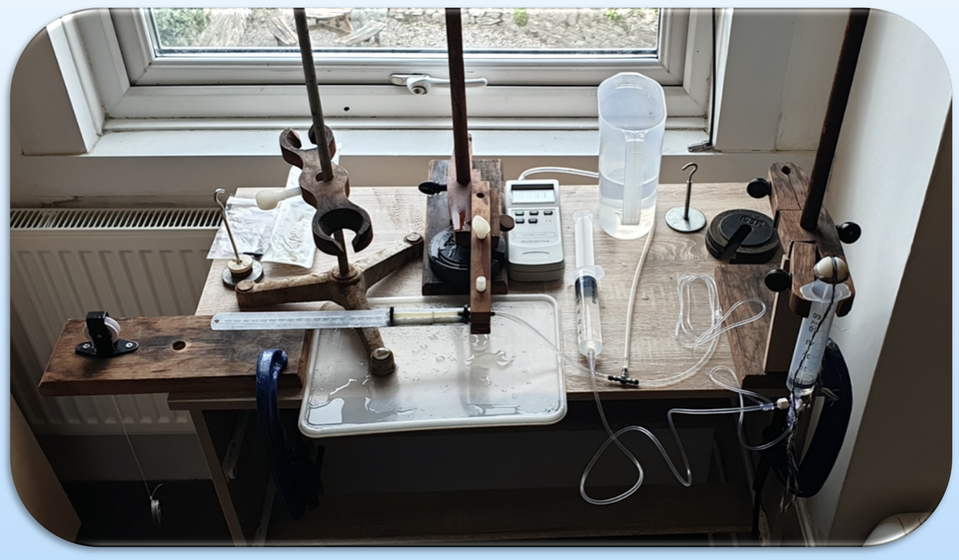


Figure 2 – Experimental rig set up for Optical Method.

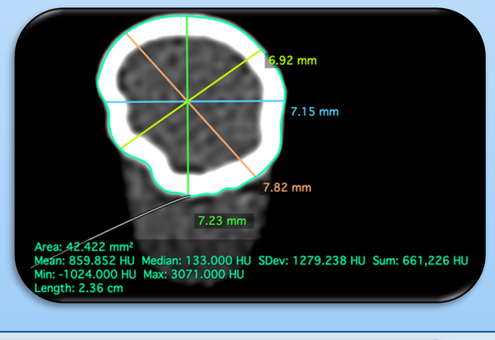


Figure 3 – CT method, Cross-sectional slice of specimen to measure multiple diameters

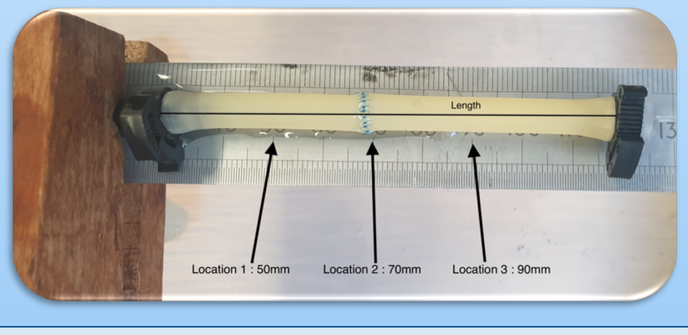


Figure 4 – Optical method, Typical photo for analysis with locations for measurements

Results

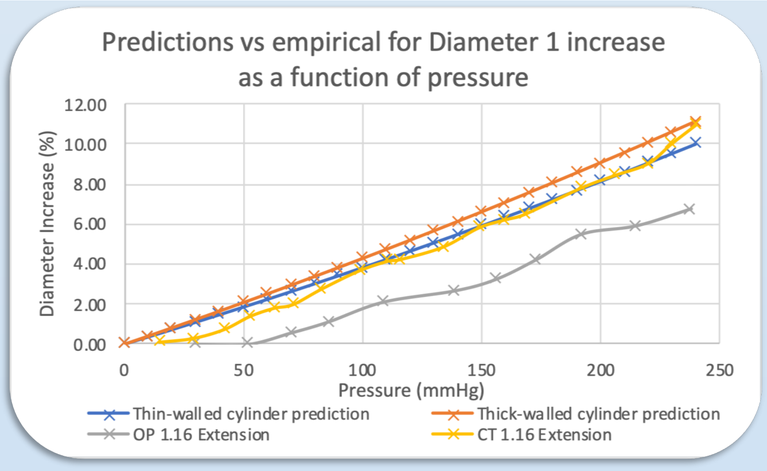


Figure 5 – Diameter increase vs. Pressure

- CT method aligns with predictions for Thin-walled cylinder
- % difference between predictions and Optical method, due to limitations

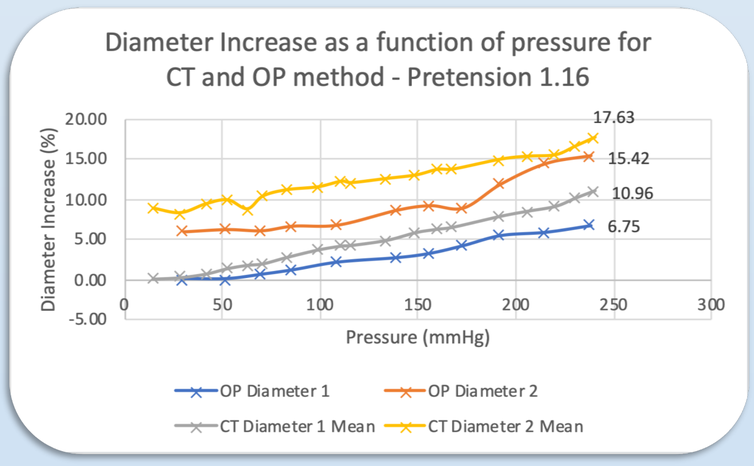
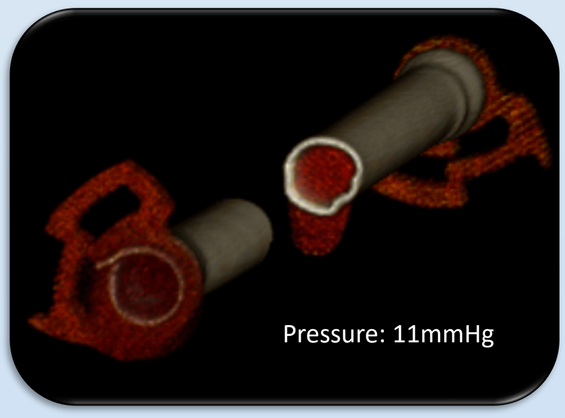
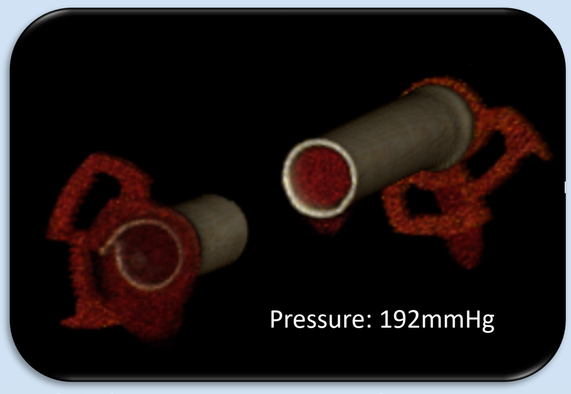


Figure 6 – Diameter increase vs. Pressure

- Diameter and length increase as a function of pressure for both methods
- % difference between the data for the two methods due to the limitations
- At maximum pressures:
  - 4.2% difference between methods for Diameter 1
  - 2.2% difference between methods for Diameter 2



CT scan: cross-sectional 3D render demonstrates how the sutures distort the specimen at low pressures



At higher pressures, the pressure overcomes the tension in the sutures making the specimen more circular

Figure 7 & 8 – 3D volume render of CT scan and cross-sectional view at pressures 11 & 192mmHg

Conclusions

- Diameter and length increase as a function of pressure and pretension
- CT method is superior in measuring diameter as multiple measurements can be taken from a cross-sectional image
- Optical method has limited accuracy
- Predictive model may not be appropriate for this investigation due to experiencing finite strain
- Deformation in anastomosed region decreases as pressure becomes enough to overcome tension in the sutures

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