ANALYSIS OF STRESS PATTERNS IN THE AORTA OF A MARFAN PATIENT WITH AND WITHOUT EXTERNAL AORTIC ROOT SUPPORT

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Introduction

Marfan syndrome is a systemic disorder of connective tissue caused by mutations in the protein fibrillin 1. It is associated with progressive aortic root dilatation and decreased aortic wall distensibility. If left untreated, this could lead to aortic dissection, which is the leading cause of death in Marfan patients. One of the methods developed to prevent progressive dilatation is the insertion of a manufactured, bespoke external aortic root support (EARS) (Pepper et al., 2010). The overall aim of this research is to determine the biomechanical implications of the EARS by applying computational methods to medical images. A preliminary assessment of the biomechanical behaviour of EARS implanted in a Marfan patient is presented here.

Method

Patient-specific reconstructions of a healthy aorta and a Marfan aorta, pre- and post-insertion of EARS, were obtained from magnetic resonance imaging (MRI). Since the aortic wall thickness could not be delineated from the images, a uniform thickness was created. The post-EARS geometry had two layers – the aortic wall and the EARS, as shown in Figure 1. The healthy and Marfan pre- and post-EARS geometries were then discretised into 100,000, 60,000 and 106,000 hexahedral element, respectively.

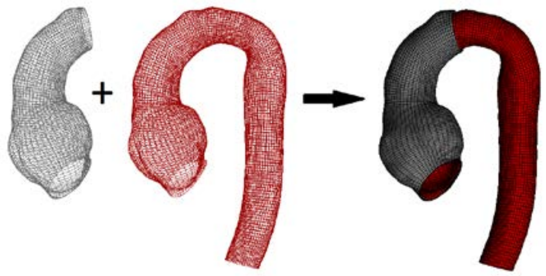

Figure 1: Discretisation of the EARS

The aortic wall was assumed to be isotropic, incompressible and homogenous. The material properties used are summarised in Table 1. A static pressure of 40 mmHg was applied and both ends of the aorta models were constrained to zero-displacement.

Property	Healthy	Marfan	EARS
Elastic modulus (kPa)	840	3000	7800
Poisson ratio	0.49	0.49	0.30
Thickness (mm)	2.0	1.0	0.64

Table 1: Material properties used in the FE model

Results

The Marfan's aortic root was up to 50% larger than the healthy aorta, while its aortic sinuses were up to 140% larger. The maximum displacements, strains and stresses were located between the sinuses in all the models. Table 2 gives a comparison of these parameters among the three models.

Parameter	[a]Pre-EARS vs Healthy	[b]Post-EARS vs Healthy	[b]Post- vs Pre-EARS
Δ Displacement	40%	-65%	-174%
Δ Strain	30%	-237%	-379%
Δ Stress	80%	65%	-75%

Table 2: Comparison of the displacements, strains and stress in the three models

Δ (Parameter) = [value1 – value2]/value1 *where* value1 *is given by* [a]*Pre-EARS and* [b]*Post-EARS*

Discussion

Reduced thickness and increased stiffness of the Marfan aorta resulted in an increased stress and strain when compared to the healthy aorta. Additionally, the high stress and strain regions were located in the sinus, which is known to exhibit progressive aortic dilatation. The addition of the EARS to the Marfan aorta reduced the stress, strain and displacements in the aortic wall. However, it was observed that while the displacement and strain in the supported aorta became lower than the healthy aorta, the maximum stress in the wall was still higher.

While the current model is useful for identifying these qualitative differences, it requires further refinement to simulate more closely in vivo conditions.

References

Pepper, J. et al., Interact Cardiovasc Thorac Surg, 10: 360-365, 2010.