THE EFFECT OF AGE, REGION, AND DIRECTION ON THE MECHANICAL PROPERTIES OF AORTIC ROOT ANEURYSMS

S. Boussias[1], E.P. Kritharis[1], D.C. Iliopoulos[2,3], D.P. Sokolis[1]

[1]Laboratory of Biomechanics, Biomedical Research Foundation, Athens, Greece;
[2]Department of Cardiothoracic Surgery, Athens Medical Center, Athens, Greece;
[3]Laboratory of Experimental Surgery and Surgical Research,
Athens University School of Medicine, Athens, Greece

Introduction

Information on the mechanical properties of sinus of Valsalva aneurysms is unavailable, although this would improve our appreciation of their modes of rupture, occurring when the hemodynamic loads exceed the strength of the sinus wall. In this report, whole-thickness wall specimens from aortic root aneurysms were biomechanically studied in vitro to determine the effect of age, region, and direction on their mechanical properties.

Methods

Aneurysmal sinus specimens were procured from 10 patients (age: 19-82 years, diameter: 45-66 mm) during elective surgical repair and assigned to groups according to region: left (LCS) vs. right (RCS) vs. non-coronary sinus (NCS), and according to direction: circumferential (CIRC; n_{LCS}=8, n_{RCS}=12, n_{NCS}=18) vs. longitudinal (LONG; n_{LCS}=8, n_{RCS}=14, n_{NCS}=21). Mechanical testing of the sinus wall was performed with a uniaxial tensile tester up to rupture. The strength and extensibility of the sinus tissue were taken respectively as the Cauchy stress and stretch at rupture, whereas maximum stiffness was taken as the maximum gradient of the Cauchy stress-stretch curve attained prior to rupture.

Results

The strength of aneurysmal sinus wall correlated inversely with the age of patients (LCS: r=-0.71, p=0.002; RCS: r=-0.64, p<0.001; NCS: r=-0.45, p=0.004), as did maximum stiffness (LCS: r=-0.57, p=0.02; RCS: r=-0.47, p=0.02; NCS: r=-0.41, p=0.01) and extensibility (LCS: r=-0.90, p<0.001; RCS: r=-0.88, p<0.001; NCS: r=-0.59, p<0.001.

As noted in Table 1, no directional differences were demonstrated in the LCS and RCS, while in the NCS the CIRC direction was stronger and stiffer than the LONG one; extensibility did not differ with direction. LONG specimens from the NCS displayed lower strength and maximum stiffness than those from the other sinuses and similarly for CIRC specimens from the RCS.

		Extensibility (-)	Strength (N/cm^2)	Maximum Stiffness (N/cm^2)
LCS	CIRC	1.84 ±0.11	138.72 ±39.85	408.91 ±95.85
	LONG	1.87 ±0.11	112.86 ±26.14	342.39 ±74.97
RCS	CIRC	1.78 ±0.09	80.56 ±17.74	225.62 ±39.68
	LONG	1.71 ±0.08	92.78 ±23.60	259.08 ±54.16
NCS	CIRC	1.82 ±0.06	153.91 ±26.62*	552.93 ±113.66*
	LONG	1.72 ±0.06	62.04 ±10.35	191.99 ±36.63

*Table 1: Failure properties categorized by region and direction. * denotes significant directional differences.*

Discussion

Evidence is submitted that aging has a deleterious effect on the strength and extensibility of the aneurysmal sinus tissue, similarly to what has been documented for ascending thoracic aortic aneurysms [Okamoto, 2002]. The significant directional differences found in the mechanical properties of NCS, resemble those of the adjacent ascending thoracic aorta [Iliopoulos, 2009; Sokolis, 2012], while the minor variations found in the LCS and RCS are consistent with a recent report on non-aneurysmal human sinuses [Martin, 2011]. Our finding that the RCS was the weakest sinus in the CIRC direction and that the NCS was the weakest sinus in the LONG direction are anticipated to provide novel insight into the pathophysiological mechanisms responsible for the highest incidence of ruptured aortic root aneurysms in those sinuses.

References

Iliopoulos D.C. *et al*, J Thorac Cardiovasc Surg, 137:101–109, 2009.

Martin C. *et al*, Eur J Cardiothorac Surg, 40:28-34, 2011.

Okamoto R.J. *et al*, Ann Biomed Eng, 30:624–635, 2002.

Sokolis D.P. *et al*, Comput Methods Biomech Biomed Engin, 15:231-248, 2012.