

## IN VITRO MODEL TO STUDY ARTERIAL WALL DYNAMICS THROUGH PRESSURE-DIAMETER RELATIONSHIP ANALYSIS

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**Abstract**— This work describes the biophysical basis of blood vessels' wall dynamics and reports a methodology developed in our laboratory to characterize mechanical vessels' wall properties and those of vascular prostheses.

Our study includes in vitro measurements of arteries, veins and ePTFE conduits placed in a circulating loop. Segments are allowed to equilibrate for a period of 15 minutes under a steady state of flow (150 ml/min) and a mean pressure of 93 mmHg, at a stretching rate of 110 beats/min.

Data analysis consisted in obtaining pressure-diameter loop in order to calculate: Incremental elastic modulus, wall viscosity, Peterson modulus, pulse wave velocity, characteristic impedance, stiffness index, cross sectional compliance and distensibility.

Incremental elastic modulus of ePTFE ( $48.56 \pm 0.82 \cdot 10^7 \text{ dyn/cm}^2$ ) was significantly higher than that of the veins ( $26.19 \pm 19.90 \cdot 10^7 \text{ dyn/cm}^2$ ) and that of the arteries ( $4.06 \pm 2.55 \cdot 10^7 \text{ dyn/cm}^2$ ).

This is an important approach, since mechanical wall dynamics plays a major role in vascular disease.

**Keywords**— arterial wall, circulating loop, viscosity, elasticity.

### I. INTRODUCTION

The main function of the systemic circulation is to hold a constant blood flow through the capillary vessels. One of the determinants of left ventricular performance is the mechanical behavior of systemic arteries. In those vessels with large diameters, the mechanical properties are mainly set by the viscoelastic individual contribution of each structural constituent (Armentano *et al.*, 1995a).

It has been reported that arterial diseases, such as human hypertension and atherosclerosis, are associated with modifications of physical properties of large arteries (Armentano *et al.*, 1998). Besides, biological or synthetic tubular segments used as vascular prostheses are characterized by a high elastic modulus and cause modifications in the arterial wall-blood dynamics. In fact, viscoelastic properties of saphenous vein or expanded

polytetrafluoroethylene (ePTFE) conduits usually used for coronary and peripheral vascular bypass grafting, differ from the native artery resulting in a mechanic mismatch that determines the development of intimal hyperplasia (Armentano *et al.*, 2004).

The aim of this work is to describe the biophysical basis of blood vessels' wall dynamics and to report the methodology developed in our laboratory to characterize mechanical vessels' wall properties and those of vascular prostheses. Experimental results will also be provided.

### II. STRUCTURAL INTEGRATION OF THE ARTERIAL WALL

The wall of the arteries consists of a tunica intima, tunica media and tunica adventitia. The intima is the innermost layer and is composed of a single layer of squamous endothelial cells, a thin basal lamina and a subendothelial layer composed by collagen, smooth muscle cells and fibroblasts (Clark and Glagov, 1985).

The tunica media is composed of smooth muscle cells, elastic sheets and collagenous fibrils. In the human being the number of elastic lamellae is related to the anatomic location of the artery; muscular arteries have only one internal and external elastic lamina while in the aorta there are about 60-90 elastic laminae. Their number decreases gradually toward the periphery of the arterial segment (Wolinsky and Glagov, 1967).

Figure 1 shows that, arterial elastic lamellae and smooth muscle cells are wrapped by a network of collagenous fibrils. An elastic lamina is concentrically arranged such that collagen bundles are better recognized through electron micrograph. Most of the collagen fascicles are oriented circumferentially but some are oriented obliquely and others longitudinally (Clark and Glagov, 1985). This lamellar unit of arterial medial structure contributes to the mechanical properties of the arterial wall.

The tunica adventitia is the outermost layer of the arterial wall and consists of dense fibroelastic tissue, vasa vasorum and nerves. This tunica is very important because the vasa vasorum supplies most of tunica media and adventitia with nutrients. The external elastic lamina is the limit between the tunica media and adventitia