FILTRATION PROPERTIES OF ARTERIES AND VEINS WITH CHANGING TRANSMURAL PRESSURE

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INTRODUCTION

Atherosclerosis is by far the leading cause of death, both above and below age 65, in the United States and all western countries. Atherosclerosis is a disorder mainly of the large, relatively thick-walled arteries; smaller arteries and veins under normal conditions are spared. Atherosclerosis appears to begin with the accumulation of extracellular lipoproteins in the artery wall and develops into lesions. This accumulation is often associated with high plasma low-density lipoprotein (LDL) concentrations, and thus lipoprotein transport into and accumulation within the artery wall is the focus of intense study. We hypothesize that qualitative and quantitative vessel-vessel differences in these processes underlie their different susceptibilities to atherosclerosis. Our group has in recent years developed a set of detailed theories, portions of which seem to be vessel-independent, that explains in a self-consistent manner, much of the water and macromolecular transport and accumulation data on these processes in large arteries. What is lacking is a detailed understanding of how they differ, and thus do or do not underlie atherosclerosis, in other tissues.

In earlier work, we developed structure-based theories to explain the filtration and mass transfer (tracer) experiments on rat aorta. One of the most important transport parameters that one needs for such models is the hydraulic conductivity (Lp). Tedgui and Lever [1] and Baldwin and Wilson [2] have measured the dependence of Lp of transmural pressures in rabbit aorta, both with and without an endothelium. Both groups found that with an intact endothelium, the hydraulic conductivity of the aorta is high at low transmural pressures, drops by circa 40% as the pressure is raised and then remains flat with further pressure increases. Our earlier theory[3] attributed this behavior to the initial compaction with increasing pressure of the proteoglycan matrix in the thin, subendothelial aortic intima, which was more than 95% void, rather than compaction of the dense media. Further compaction is prevented by the intima's collagen constituent.

MATERIAL AND METHODS

We adapted the above-mentioned technique to the smaller rat and to these other vessels, the latter of which has a difficult geometry. After anesthetizing, the animal is under a respirator. The vessel of interest is isolated and ligate. A phosphate buffered saline (with pH7.4 and 37^{o}C) containing Bovine Serum Albumin (4%), Sodium Nitrate (10^{-3} M) and Trypan Blue (0.03%) is applied into the vessel. The pressure reservoir is connected to the perfusate and pressure monometer, which controls the pressure. To measure the transmural flux at designed pressure, the upstream reservoir is connected via a stopcock to a 1.2 m Tygon tubing (0.05cm ID), a portion of which is horizontally positioned adjacent to a meter rule. The downstream end of the tubing is connected to the vessel. A bubble is injected into the capillary tubing and the bubble's position relative to the ruler is recorded. The external diameter and length of the cannulated segment of the vessel are measured using a mechanical caliper accurate to 0.1mm.

RESULTS

We presented preliminary data for the Lp of aorta (lumen pressure is 100 mmHg), pulmonary artery (25 mmHg), and inferior vena cava (5 mmHg), with and without endothelium. We focus on these vessels because the pulmonary artery represents an intermediate-pressure artery that only becomes atherosclerotic under pulmonary hypertension, and the vena cava a low pressure vein that is disease resistant. The aortic wall, at about 150 μm, is the thickest-walled among these three vessels, and thus has the greatest hydraulic resistance. For the aorta, Lp is circa 10^{-9} mm^{2}s/g (Figure 1); for the pulmonary artery (~90 μm) it is 10^{-8} mm^{2}s/g (Figure 2), and for the inferior vena cava (~60 μm) it is 10^{-7} mm^{2}s/g (Figure 3). Over the last year, we have succeeded in removing the endothelia of these vessels and measuring the wall resistances or hydraulic conductivities of these vessels, both with and without endothelia on the same vessel, in rats.

DISSCUSIONS

In this paper we begin by comparing our aortic Lp data performed on rats with those ([1], [2]) for rabbits and find surprisingly little difference. We also compare Lp of each vessel with and without endothelium to assess the endothelium's contribution to the vessel's hydraulic resistance for each vessel. The hydraulic resistance of a given vessel is of the same order of magnitude both with and without an intact endothelium, but increases by a factor of order 2-4 upon endothelial removal. The trends of our result agrees with Baldwin & Wilson [2] and quantitively agrees with Tedgui & Lever [1]). We also compare the different vessels with each other, a comparison that is coupled to our ultrastructural studies, in order to define the dominant transport influences for corresponding convective-diffusion-and-reaction models. We find that the trends of the pulmonary artery and inferior vena cava are similar to the aorta both with and without endothelium. This may suggest that both pulmonary artery and inferior vena cava may have intima-like layer existed. But under their normal physiological pressure, aorta has been fully compressed, pulmonary artery is partially compressed, inferior vena cava due to its low pressure may not be compressed. These experiments also allow calculation of certain parameters in these theories. We present one such theory for the inferior vena cava. Solution of the model equations will allow comparison with Tompkins'[4] data for tracer concentration as a function of distance into the vessel wall. We shall also compare with our own data of the size of a tracer spot in the vessel wall when cut open axially and viewed *en face* as a function of tracer circulation time.

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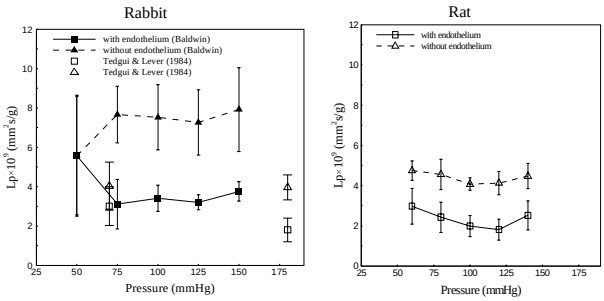

Figue1. The dependence of the hydraulic conductivity of rat aorta on transmural pressure.

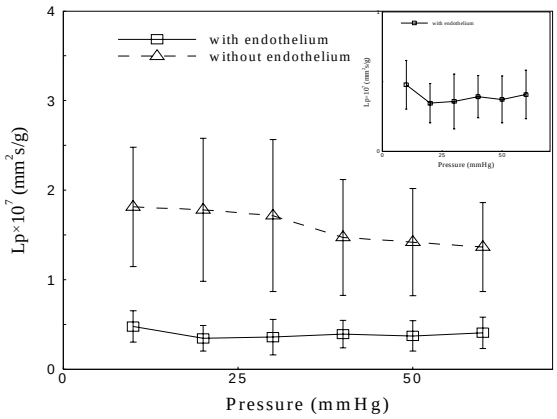

Figure 2.The dependence of the hydraulic conductivity of rat inferior vena cava on transmural pressure.

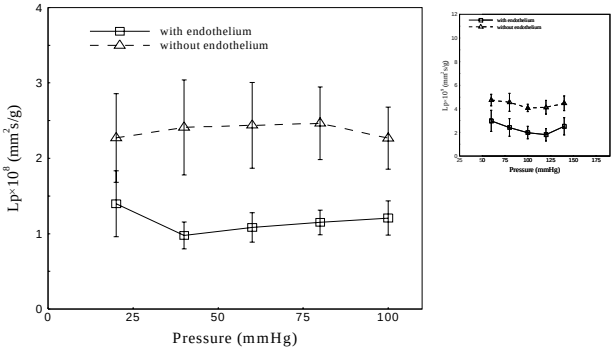

Figure 3. The dependence of the hydraulic conductivity of rat pulmonary artery on transmural pressure.