
ARTERIAL CALIBER AND SHEAR STRESS: STUDIES ON CEREBRAL AND RETINAL VESSELS IN MAN (Abstract)*. Thesis. Göteborg, Sweden, 1995.

SANDRO L. ROSSITI**

This dissertation is based in 5 original articles¹⁻⁵ concerning the remodeling of arterial caliber to changes in blood flow and its relation to blood-flow-induced wall shear stress (SS). The arterial wall responds morphologically and metabolically to hemodynamic stimuli. Instantaneous changes in hemodynamic conditions lead to adaptations of vessel tone, and long-term changes lead to anatomical remodelling. SS exerts a major influence in this process, acting via endothelial cell mediation. While pressure gradients drive the flow, the viscosity of the blood elements opposes the flow. SS is the shear force per unit area transmitted by the flow of blood to the luminal surface of the endothelial cell layer. It is a function of the gradient of the tangential blood flow velocity and of the blood viscosity, and it exerts a tractive effect on the endothelium in the direction of flow.

The studies involved: a) mathematical analysis of the branching of the internal carotid artery system in normal angiograms¹; b) analysis of the branching of the retinal arterioles in fundus photographs of patients with non-vascular retrobulbar optic nerve lesions before and after the development of optic atrophy²; c) analysis of the temporal heterogeneity of cerebral blood flow velocities in normal volunteers^{3,4}; d) SS in cerebral arteries of patients with an arteriovenous malformation (AVM) of the brain⁵.

The results indicate the presence of a constant relation between SS and cerebral and retinal arterial caliber in man. In bifurcations of the internal carotid arterial tree and of the retinal arteriolar tree the volumetric flow of the stem vessel seems to be distributed to the branches such that the volumetric flow in each vessel is approximately adjusted to the cube of the vessel radius ("Principle of Minimum Work"). Thus, SS seems to be constant over the studied segments of the cerebral and retinal arterial trees because the flow rate influences the shear stress proportionally to the third power of the vessel radius. The studies also showed that these vessels, when subjected to long-term changes in blood flow, reshape themselves in order to maintain SS constant. Chronically decreased metabolic demand, and presumably blood flow, in the retinal arterial tree results in decrease of vessel calibers, but SS seems to be regularly distributed in the vessel networks both before and after caliber remodeling. In the presence of chronically increased blood flow in a localized portion of the cerebral arterial tree provoked by an AVM, the arteries transporting the increased blood volume demanded by the arteriovenous shunt seem to dilate in order to maintain SS constant. Thus, it is reasonable to conclude that the arterial caliber is determined locally in each vessel segment to maintain a constant relation between blood flow and vessel radius, and that SS-sensitive mechanisms are a main factor in this process. However, blood flow and SS in a given artery vary considerably over time, presenting spontaneous irregular oscillations over time. The hypothesis on the relation between SS-sensitive mechanisms and control of arterial caliber would be implausible, should these oscillations be just a random feature. Anyway, the time-course of the time-averaged flow velocity (and thus SS) does not seem to result from random influences. Nevertheless, the pulse oscillations vary less

predictively than the time-averaged flow velocity on a beat-to-beat basis. This finding indicates that the physiological mechanisms determining the pulse oscillations may be more complex than those of the time-averaged flow velocity, or alternatively that an irregular beat-to-beat method variation influenced the measurements. The temporal heterogeneity of SS was taken into account when estimating SS in the study of AVM patients.

Mapping SS in the basal cerebral arteries may provide new insight into the physiology and pathology of vascular remodeling following altered blood flow states, as well as into the pathogenesis of atherosclerosis, intracranial saccular aneurysm, intimal dissection and arteriovenous fistula formation. Hence, it may result in improved tools for cerebrovascular diagnosis with potential consequences for assessment of prognosis and follow-up of these categories of patients.

REFERENCES: 1. Rossitti S, Löfgren J. Vascular dimensions of the cerebral arteries follow the principle of minimum work. *Stroke* 1993, 24:371-377. 2. Rossitti S, Frisé L. Remodelling of the retinal arterioles in descending optic atrophy follows the principle of minimum work. *Acta Physiol Scand* 1994, 152:333-340. 3. Rossitti S, Stephensen H. Temporal heterogeneity of the blood flow velocity at the middle cerebral artery in the normal human characterized by fractal analysis. *Acta Physiol Scand* 1994, 151:191-198. 4. Rossitti S, Volkmann R. Fractal dimension and temporal correlation of the time course of transcranial Doppler pulsatility index. *J Vasc Invest* 1995, 1:44-49. 5. Rossitti S, Svendsen P. Shear stress in cerebral arteries supplying arteriovenous malformations. *Acta Neurochir (Wien)*, in press.

KEY WORDS: arteriovenous malformations, cerebral arteries, Doppler ultrasound, fractals, hemodynamics, optimality concepts, retinal arteries, shear stress, vasodilation.

*This dissertation was submitted to the Göteborg University in June 6, 1995, as a part of the requirements for the degree of Doctor in Medicine. The studies were carried out at the Department of Neurosurgery, Institute of Clinical Neuroscience, Göteborg University, Sweden. ["Calibre e shear stress: estudos em artérias cerebrais e retinianas humanas". Tese de Doutorado, Departamento de Neurocirurgia, Instituto de Neurociência Clínica, Faculdade de Medicina, Universidade de Göteborg, Suécia.]

**Address: Nordenskiöldsgatan 6 - S-413 09 Göteborg - Sweden.