Form and haemodynamics of the circulus arteriosus cerebri (willisII)

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SUMMARY AND CONCLUSIONS

This thesis deals with the vascular diameters of the circle of Willis in relation to the flow in this arterial network and vice versa. The basic question is wether the diameters of the arteries which form the circle of Willis are adapted to the flux that is present under normal circumstances?

The background of this question and the successive steps that have to be made to come to an answer are discussed in Chapter I.

Chapter II reports on a mathematical model, consisting of 5 arterial segments, designed to study the haemodynamics of one posterior communicating artery. The variables in the model are the diameter of the posterior communicating artery, the resistance in the vertebral artery and the ratio of the two peripheral resistances. From this study the haemodynamical mechanisms become clear. The total flux in the model and the fluxes in the efferent vessels are dominated by the peripheral resistances, whereas the fluxes in the afferent vessels and in the communicating artery are strongly influenced by their own, comparably small, resistances. Moreover, it appeared that the strongest influence of the diameter of the posterior communicating artery is within the range of anatomical variation.

The model showed a "compensatory capacity" for changes of the resistances in the afferent vessels that is virtually independent of the diameter of the posterior communicating artery, which can be understood from the mechanism indicated above.

In Chapter III the previous mathematical model is extended to an 18-segment model of the circle of Willis and its attributaries. The mechanisms found in the simple model appear not to be modified by the extension.

Again, the influence of diameters of the communicating arteries and the segments of the circle of Willis turns out to be considerable, especially in the range of the anatomical variations of the diameters. For example, any asymmetry of the system with the exception of the vertebral arteries appears to induce a flux in the anterior communicating artery.

Special attention has been paid to the possible occurrence of a "dead point" in the flow through the posterior communicating arteries.

As it came out such a "dead point" is not to be expected in physiological conditions, even in the presence of the posterior perforating arteries.

In Chapter IV a model is presented in which the mathematical description of the flow is drastically simplified by neglecting pulsatility and vesselwall elasticity. The purpose of the simplification is to make a more analytical approach possible. Comparison with the results from the previous, more sophisticated model yielded good equivalency of both models for the time averaged flux. With this model the mechanisms that govern the fluxes can be described algebraically, through which the relations between form and haemodynamics can be demonstrated more simply and conveniently.

From this part of the study it can be concluded that the sensitivity of the fluxes to small changes of the diameters is based on the principles of the Wheatstone-bridge, known from electrical circuit theory for its high sensitivity.

Chapter V and Chapter VI deal with the morphological part of the study. Chapter V reports on a univariate and bivariate analysis of vessel diameters obtained from 100 circles of Willis.

This data yielded no evidence of differences between left and right sided vessels in the sample with the exception of the vertebral artery. An important source of variation is the general sizefactor. When the data is cleared from this general size variation, correlation coefficients reveal interesting relations between the vessels. The posterior communicating arteries are correlated positively to the ipsilateral carotid artery, whereas a strong inverse relationship exists with the basilar artery and the precommunicating part of the ipsilateral posterior cerebral artery. These relationships can be understood from the expected patterns of the blood flow in these vessels. Similar relationships can be found in the anterior part of the circle of Willis and in the vertebro-basilar junction. In a different manner, the relation between blood flow and vessel size within the circle of Willis can be demonstrated in an "intuitive" model by relating the ratios of the sizes of afferent and efferent arteries to the sizes of the posterior communicating arteries. The supposed correlations of the outcome of this "intuitive" model with the size of the communicating arteries appeared to be highly significant.

It is concluded that the variations of the circle of Willis are related to the individual variations of the blood flow in this arterial network.

Since the number of variables per individual is large multivariate statistical techniques are the most appropriate method to gain insight in the relations of vessel sizes that exist within the circle of Willis.

In Chapter VI the results of a principal component analysis of the data from Chapter V are discussed. This analysis was carried out with the size-standardized data. In general, inverse relationships were found between vessels in which it is expected that, based on the haemodynamical relations, the fluxes in both vessels have a "constant" sum. The relations found in Chapter V are again clearly demonstrated in this multivariate analysis. The homonymous efferent arteries appear to be closely related and show variation that is independent of the other vessels. Together the first six principal components explain 69% of the variance.

Based on these data a hypothesis is presented that attributes the origin of the variation of the circle of Willis to differential growth in the head-neck region during the first two decades of life.