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Zależności anatomiczne i hemodynamiczne występujące między umiejscowieniem stentów w wybranych odcinkach koła tętniczego mózgu a odgałęzieniami tętnic wewnątrzczaszkowych

Streszczenie w języku angielskim

Cerebrovascular diseases are a growing clinical and social problem. The cerebral circulation – the site of their development – is distinguished by its complex anatomy and close connection to the proper functioning of the brain. Its distinctiveness is particularly evident in the case of the perforating arteries – small arteries penetrating the nervous tissue of the brainstem and the anterior and posterior perforated substances. Although the diameter of the perforators often does not exceed 0.7 mm, they supply structures vital to human life and are involved in the development of various pathologies (lacunar infarct, intracerebral hemorrhage, dementia, among others). Most importantly from the pathophysiological reasons, they branch directly from the high-pressure intracranial arteries, therefore they appear to be particularly vulnerable. A wide variety of neurovascular interventions are being performed in the clinical setting, including stents implantations, which can be a source of complications from the perforating arteries. It is therefore crucial to study hemodynamics, and one of the most widely used methods is computational fluid dynamics.

Previous studies on the perforating arteries have used optical techniques only and lacked three-dimensional models to enable precise morphological and simulation studies. The main aim of the study was to develop a methodology for obtaining geometric models of the perforating arteries branching from the middle cerebral artery and the basilar artery. Additional aims were to describe the morphology of the perforators branching sites, the spatial relationships between stent struts and the perforators branching sites, to evaluate perforators patency, as well as to assess the feasibility of performing computer simulations of hemodynamic conditions.

The main result of the study is the methodology for obtaining three-dimensional models of the perforating arteries. They are obtained by injecting carefully prepared specimens of the human brain with a contrast medium and scanning with the use of microcomputed tomography after fixation in formaldehyde solution. It is the use of microtomography scanner that is crucial, as the radiological results are about 10 times more accurate than commonly used imaging techniques. The adequacy of the injection pressure and the precision of visualization were confirmed in additional experiments (also compared to standard CT). The method is reproducible, provides high-quality models and does not require expensive reagents.

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Additional objectives of the study were realized using a collection of the specimens of the middle cerebral artery and the basilar artery with their perforators (165 and 158 perforating arteries in total, respectively). The geometry of the perforators branching sites was studied – areas of hemodynamic interest, as they connect the high-pressure parent arteries with arterioles. It was discovered that branching sites are not circular but oval in shape and statistical analysis using linear mixed models revealed that the rotation of the oval relative to the parent artery is related to the perforator course, while the severity of stenosis may increase with age. This is particularly interesting finding in the context of small vessel disease and dementia pathophysiology.

Spatial relationships between stent struts and perforators branching sites as well as assessment of their patency were studied by calculating coverage percentages of the branching ostia by stent struts of different widths (typical of classic and so-called flow diverting stents). The degree of coverage was higher in case of classic stents, which are constructed of with wider struts, and amounted to up to 50% for most perforating arteries. For flow diverters, the percentage of coverage was about 2-3 times lower. However, it should be stressed out that smaller perforators can be completely covered by stent strut, which is especially true for classic stents. The described phenomenon may underlie the clinically observed ischemic complications after selected neuroradiological procedures.

Basic simulations of blood flow through a three-dimensional model of the basilar artery were carried out, demonstrating that it is possible to study the hemodynamic conditions prevailing in the perforating arteries. Complex conditions at the perforator branching sites that may be responsible for their narrowing were visualized. This topic requires further in-depth research.