脳動脈のコンピューター血流動態解析

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（主　査）

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論 文 内 容 要 旨

A relatively simple approach to reconstruct cerebral vessels as 3D numerical grids is described. The method accurately duplicates their geometry to provide computational replicas, aiming to study intracranial aneurysmal blood flow. Initial images were obtained by using medical imaging technique, such as MR angiography, CT angiography, or 3D digital subtraction angiography. The data were collected in DICOM format and converted by a DICOM reader into a 3D gray-scale raster image. The image is then processed by using commercial visualization and mesh generation software, which allowed extraction of the luminal surface of the blood vessel (by using the isosurfacing technique). The subsequent final output is tetrahedral grid that can be directly used for patient-specific simulations of blood flow. An angiographic categorization of saccular intracranial aneurysms (ANs) into three categories named Sidewall (SW), Sidewall with Branching Vessel (SWBV) and Endwall (EW) ANs is designed according to the angiographic pattern of their parent arteries. Computational Flow Dynamic Analysis (CFDA) of simple models representing the three aneurysmal categories aiming to analyze their geometry related risk factors like neck width, parent artery curvature and angulation of branching vessels. Application of the proposed categories and the CFDA on 68 aneurysmal geometries from real patients angiograms (45 ruptured and 23 unruptured cases) has been done. In the CFDA studied cases, the wall shear stress, blood velocity and pressure maps are examined and correlated with ANs ruptured points. Statistical analysis of the ruptured cases using multiple regression analysis reveals a significant statistical correlation between aneurysmal depth and both neck size ($P<0.0001$) and caliber of draining arteries ($P<0.0001$). Wider neck ANs or those with wider caliber of drainers are found to be high flow ANs that tend to rupture at larger size. Smaller neck ANs or those with smaller caliber of drainers are found to be low flow ANs that tend to rupture at smaller size. Aspect ratio (depth/neck>1.6) of the ruptured cases is found to be 100% in the SW and SWBV categories while 28.75% in the EW ANs. The application of the standardized categories enables the comparison of results for various ANs geometries thus assisting in the process of management and decision-making. The proposed categorization may be promising to understand the natural history of saccular intracranial ANs.

審 査 結 果 の 要 旨

A relatively simple approach to reconstruct cerebral vessels as 3-Dimentional numerical grids is described. The method accurately duplicates their geometry to provide computational replicas, aiming to study intracranial aneurysmal blood flow. Initial images were obtained by using medical imaging technique, such as Magnetic Resonance Angiography, Computerized Tomography Angiography, or 3-Dimentional Digital Subtraction Angiography. The data were collected in DICOM format and converted by a DICOM reader into a 3-Dimentional gray-scale raster image. The image is then processed by using commercial visualization and mesh generation software, which allowed extraction of the luminal surface of the blood vessel (by using the isosurfacing technique). The subsequent final output is tetrahedral grid that can be directly used for patient-specific simulations of blood flow. An angiographic categorization of saccular intracranial aneurysms into three categories named Sidewall, Sidewall with Branching Vessel and Endwall aneurysms is designed according to the angiographic pattern of their parent arteries. Computational flow dynamic analysis of simple models representing the three aneurysmal categories aiming to analyze their geometry related risk factors like neck width, parent artery curvature and angulation of branching vessels. Application of the proposed categories and the Computational flow dynamic analysis of 68 aneurysmal geometries from real patients angiograms (45 ruptured and 23 unruptured cases) has been done. In the Computational flow dynamic analyzed studied cases, the wall shear stress, blood velocity and pressure maps are examined and correlated with aneurysmal-ruptured points. Statistical analysis of the ruptured cases using multiple regression analysis reveals a significant statistical correlation between aneurysmal depth and both neck size ($P<0.0001$) and caliber of draining arteries ($P<0.0001$). Wider neck aneurysms or those with wider caliber of drainers are found to be "high flow" aneurysms that tend to rupture at larger size. Smaller neck aneurysms or those with smaller caliber of drainers are found to be "low flow" aneurysms that tend to rupture at smaller size. Aspect ratio (depth/neck$>$1.6) of the ruptured cases is found to be 100% in the Sidewall and Sidewall with branching vessel categories while 28.75% in the Endwall aneurysms. The application of the standardized categories enables the comparison of results for various aneurysmal geometries thus assisting in the process of management and decision-making. The proposed categorization may be promising to understand the natural history of saccular intracranial aneurysms.

よって，本論文は博士（医学）の学位論文として合格と認める。