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THE EFFECT OF STENOSES AND IRREGULAR FLOW RATES IN HUMAN BRAIN VENTRICULAR SYSTEMS

EDI AZALI HADZRI

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
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APRIL 2014

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To my beloved mother, father, family members and friends

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ABSTRACT

Apart from irregular flow rate, hydrocephalus can also occur due to flow obstructions of cerebral spinal fluid (CSF) flow from the ventricles to the subarachoid space such as stenosis that builds up at the aqueduct. Since the size of the stenosis can affect the seriousness of hydrocephalus, simulation study can be used as cheaper and more detailed method to provide internal flow pattern inside the aqueduct. In this study, three dimensional models of the third ventricle and the aqueduct of Sylvius derived from MRI scans were constructed and the flow patterns were modeled by using MIMICS and CFD software. The constructed region of interest (ROI) was regarded as rigid wall and steady state flows were assumed. Different flow rates were simulated at the Foramen of Monro and several stenosis of various sizes were modeled at the middle of the aqueduct of Sylvius at a fixed location. These were made corresponding to normal patients with variation of CSF flow rates physiologically, and abnormal patients with tumor causing obstruction to or within the aqueduct of Sylvius, respectively. The results shows that the small difference of stenose sizes (1.2 times) is outweighed the difference of the flow rate (2 times) for contributions to abnormal and hydrocephalus. Unlike normal flow rates, there are flow recirculation appeared in the region of interest (ROI) in hydrocephalus cases. The flow recirculation might cause the pressure increase for abnormal flow rates to stay around at 50% - 60% of range for 10% of increment in stenose size. The analysis of the CSF flow patterns can provide a possible potential risk indicator of stenosis severity to the patients.

ABSTRAK

Selain daripada kadar aliran yang tidak teratur, hydrocephalus juga boleh berlaku disebabkan oleh halangan aliran terhadap aliran cecair tulang belakang serebrum (CSF) dari ventrikel ke ruang subarachoid seperti stenosis yang terbina di saluran Slyvius. Disebabkan saiz stenosis memberi kesan kepada tahap hydrocephalus, kajian simulasi boleh digunakan sebagai kaedah yang lebih murah dan terperinci untuk menyediakan corak aliran di dalam saluran Slyvius. Dalam kajian ini, model tiga dimensi ventrikel ketiga dan saluran Slyvius diperolehi daripada imbasan MRI telah dibina dan corak aliran dimodelkan dengan menggunakan perisian MIMICS dan CFD. Kawasan dalam perhatian (ROI) yang dibina dianggap mempunyai dinding tegar dan aliran berkeadaan mantap telah diandaikan. Kadar aliran yang berbeza telah simulasi di Foramen Monro dan beberapa stenosis dalam pelbagai saiz telah dimodelkan di tengah-tengah saluran Sylvius di lokasi yang tetap. Ini dibuat bagi menyerupai pesakit biasa dengan perubahan kadar aliran CSF fisiologi dan pesakit yang tidak normal dengan tumor yang menyebabkan halangan kepada atau dalam saluran Sylvius. Keputusan menunjukkan bahawa perbezaan kecil saiz stenose (1.2 kali) adalah melebihi perbezaan kadar aliran (2 kali) yang menyumbang kepada abnormal dan hydrocephalus. Tidak seperti kes normal, terdapat peredaran aliran semula di dalam kes hydrocephalus. Peredaran aliran semula mungkin menyebabkan peningkatan tekanan bagi kadar aliran yang tidak normal kekal sekitar 50% - 60% daripada julat 10% daripada kenaikan saiz stenose. Analisis corak aliran CSF boleh memberikan petunjuk potensi risiko keseriusan stenosis kepada pesakit