Thoracic aorta flow sensitive 4D MR imaging in hypertension

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Introduction: Previous studies have employed flow sensitive 4D MR imaging to characterize the complex flow patterns in the thoracic aorta of healthy volunteers and patients with aortic pathologies[1,2].
Objective: To evaluate the blood flow patterns of thoracic aorta in hypertension using flow sensitive four-dimensional MR imaging at 3T.
Material and Methods: 30 hypertensive patients underwent flow sensitive 4D MR scan after IRB approval and written informed consent. All patients were first diagnosed as hypertension without any medical treatments. According to the 1999 WHO/ISH hypertension guidelines, the patients were grouped as grade 1(n= 14), grade 2 (n= 10) and grade 3 (n= 6). Studies were performed on a 3T scanner (MAGNETOM Verio, Siemens Healthcare, Erlangen, Germany) with a 32-channel body coil. Data preprocessing, quantification and visualization were performed using a prototype 4D-Flow WIP package. On the phase-contrast MR angiograms (PCMRA), six analysis planes transecting the aortic lumen were automatically positioned. The flow data of each plane including flow rate, velocity and pressure was automatically quantified over the cardiac cycle. According to the formula: $PI=(V_s-V_d)/V_m$ and $RI=(V_s-V_d)/V_s$, pulsatility index (PI) and resistance index (RI) were calculated with V_s, V_d, and V_m representing the systolic, diastolic and mean velocities, respectively. Image quality was independently evaluated by two experienced cardiovascular radiologists based on PCMRA, streamlines and particle traces visualizations using a four-grade scale (1-poor to 4-excellent).
Results: All patients were successfully examined with 4D PC-MRI. PI and RI increased with the growth of hypertensive grades, while mean velocity (V_m), flow rate (F) and pressure (P) decreased with the growth of hypertensive grades. As for PI, RI, V_m, F and P, there were statistical differences among grade 1, 2 and 3 ($P<0.05$). Agreement between the two radiologists was good (k = 0.78). The fastest flow was observed in the distal aortic arch (DAoA) in 25/30 cases. Helicity was present in hypertension of grade 2 and 3 in the ascending aorta (AAo) in 13/16 patients, DAoA (6/16) or descending aorta (DAo) (2/16). More helical vectors were observed in higher hypertensive grades.
Discussion: PI and RI are the relevant flow parameters in hypertension. PI reflects arterial compliance and elasticity, RI reflects vascular relaxation condition. Our study found that PI and RI increased with the growth of hypertensive grades; this suggests that the aortic compliance, elasticity and relaxation limited the growth of hypertensive grades. This may be due to the very early damage to the aortic intimabut needs further study to be confirmed. In this study, we observed that the fastest flow was mostly in the DAoA plane. According to the principle of mechanics, under the effect of strong alternating stress the endothelial cells are susceptible to fatigue damage. This is in contrast to the common location of the aortic plaque[4].
Conclusion: The findings illustrate that sensitive flow 4D MR imaging can evaluate the hemodynamic patterns of thoracic aorta in hypertension. Future work will focus on the significance of these findings, and then reveal the development of aortic pathologies, such as atherosclerosis and dissection.
References: Hope MD.et al, JMRI, 31:711-718(2010); Frydrychowicz A.et al, JTCS, 136:400-407(2008); Bogren HG.et al, J MRI.et al,10 :861-869(1999).

Fig.1 The flow parameters of the three hypertensive grades

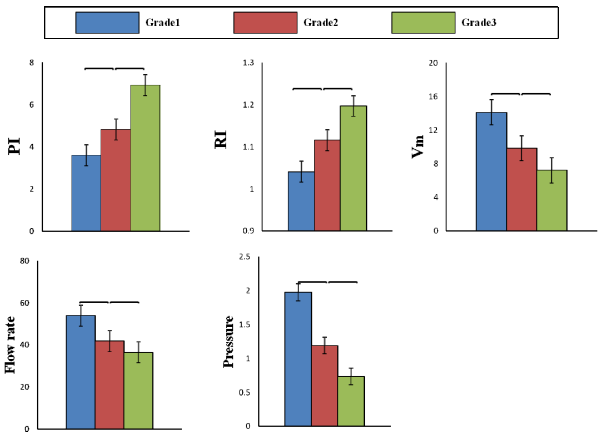
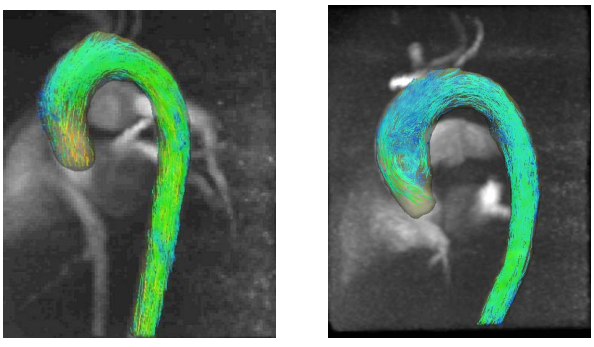


Fig.2 Particle traces visualization of vortexes in the Aorta



Grade 1 Grade 2