MR Flow Measurements in Peripheral Arteries during Reactive Hyperemia

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Introduction

Recently, the use of drugs to stimulate the growth of collateral arteries (arteriogenesis) has been proposed as a potential treatment for obstructive coronary and peripheral artery disease [1]. Therapeutic effects in studies with small animal [2] and porcine models [3] have been evaluated in terms of perfusion with invasive pressure measurements and invasive perivascular flow probes or microsphere counts after sacrificing the animal. Evaluations of treatment in human subjects require non-invasive approaches. However, methods in clinical practice, such as the ankle-bracchial index, treadmill test, doppler sonography, and strain-gauge plethysmography, are either lacking accuracy or they are error-prone. This study investigates the feasibility of MR phase contrast (PC) cine imaging in the iliac arteries to assess flow parameters for the evaluation of peripheral arterial obstructive disease during post-ischemic reactive hyperemia.

Methods

PC through-plane flow measurements were performed on both legs of 6 normal volunteers (24-35 years) and on 7 patients (56-76 years) with peripheral arterial obstructive disease according to Rutherford class I catgegory 2-3 whose symptoms included pain in the legs while walking less than 200 m. A fast spoiled gradient echo sequence with flow encoding and segmented k-space acquisition was implemented on a 1.5 T Sonata system (Siemens Medical Solutions, Erlangen, Germany) with gradients supporting 40 mT/m amplitude and 200 T/m/s slew rate (TE/TR = 3.6/5.3 ms, flip angle = 15°, BW: 650 Hz/pixel, FOV = 280 mm × 210 mm, acquisition matrix = 256 × 96, typical venc = 120 cm/s). A temporal resolution of 76 ms was achieved with view sharing such that a complete cine data set was acquired every 8 heart beats [4]. Cine data sets were continuously acquired over the iliac artery before, during, and after inflation of a thigh cuff to suprasystolic pressures (approx. 200 mmHg). Each leg of each patient and volunteer was measured up until three minutes after pressure release in the cuff which had been inflated for one minute. For comparisons, additional measurements with three minute cuff inflations were acquired in the volunteers. The flow analysis was perfomed with a customized software tool written in Matlab (The Mathworks, Inc.; Natick, MA) to assist in adjusting ROIs in the presence of motion from breathing and the cardiac cycle.

Results

The flow waveforms of all volunteers were of triphasic shape and showed a mean arterial blood flow of 7.7±1.3 ml/s and a mean peak flow during systole of 48.2±7.6 ml/s during rest (prior to the inflation of the cuff). After cuff inflation for one minute and pressure release the mean flow increased to 16.6±2.1 ml/s which corresponds to an average flow reserve of 126.8±7.6% as shown in the example in Fig. 1. These measurements increased to 22.9±3.3 ml/s (flow reserve of 202.6±58.2%) after occlusion for three minutes. The patients had a statistically significant lower mean flow ($p<0.05$) of 12.7±3.6 ml/s after one minute occlusion which corresponds to a statistically significant lower ($p<0.0001$) flow reserve of 44.2±24.3%. In contrast to the normal volunteers, flow waveforms of the patients were lacking the triphasic shape since no reverse flow occurred during diastole.

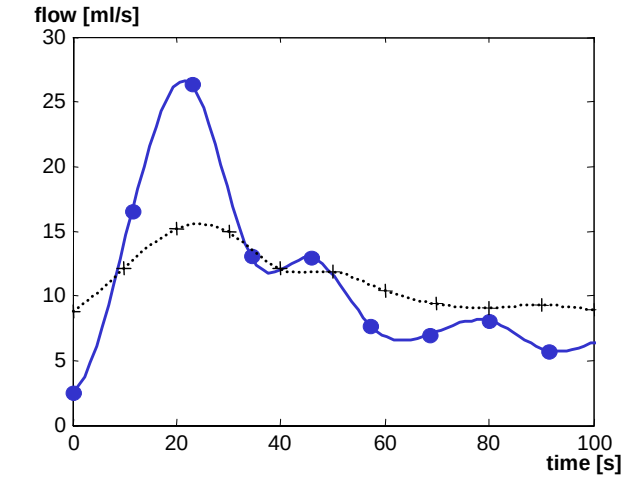

Fig 1.: Mean flow during reactive hyperemia for volunteer (solid line) and patient (dotted line)

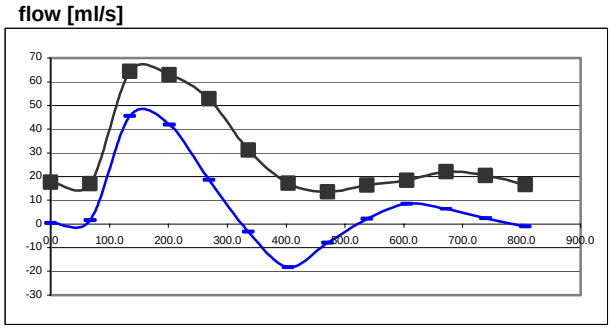

Fig 2.: Flow waveform within cardiac cycle of a normal volunteer at maximum flow (squares) and at rest (dashes).

Conclusion

This study demonstrates that MR cine flow measurements are feasible during reactive hyperemia in the lower extremities and showed large differences in mean flow and flow reserve as a normalized measure between the patient population and normal volunteers. Longer occlusions lead to an increase in the flow reserve in volunteers. Further investigations with normal volunteers from the same age group as the patients are required to assess the feasibility for monitoring therapeutic effects with treatments for the stimulation of collateral artery growth. The MR acquisition could benefit from incorporating partially parallel acquisition (PPA) techniques in order to decrease the time between complete cine data sets. Detailed analysis of changes in the flow waveform within the cardiac cycle between rest and maximum flow in reactive hyperemia (Fig. 2) could be an interesting aspect for future analysis as has been shown in ultrasound studies [5].

References

[1] Schaper *et al*., *Cardiovasc Res* **43**, 835-7, 1999.
[2] Höfer *et al., Cardiovasc Res* 49, 609-17, 2001.
[3] Buschmann *et al., Atherosclerosis* 167, 33-43, 2003.
[4] Markl *et.al., Magn Reson Imaging* **19**, 669-76, 2001.
[5] Sensier *et al., Eur J Vasc Endovasc Surg* **20**, 29-35, 2000.