Assessment of Lower-Limb Perfusion using Rapid 3D Spiral Trajectories

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Introduction Due to promising new interventional techniques such as gene or stem cell therapy, there is increased need for accurate measurement of perfusion deficits and post-therapy improvements. First-pass perfusion imaging using bolus tracking is a validated potentially quantifiable technique [1,2], but requires sufficient volumetric coverage with high temporal resolution. In this study, first-pass perfusion of the lower limb is assessed using a variable-density [3] stack-of-spirals trajectory [4] to obtain full volumetric coverage with high temporal resolution. The temporal data was then processed to quantify perfusion. To verify this technique, normal volunteers and patients with peripheral vascular disease (PVD) (ankle-brachial index (ABI) < 0.9) were scanned.

Theory A variable-density stack-of-spirals trajectory with a spoiled gradient-echo acquisition was implemented with spectral-spatial excitation pulses [5] used to suppress fat. The study was performed by scanning the infrapopliteal region of both legs repeatedly to obtain temporal information over a large volume. The protocol involved occluding the ischemic leg by inflating a blood pressure cuff above the subject's systolic blood pressure level. Then, 20 sec into the scan, 10 cc of Magnevist (contrast agent) was injected in the arm over 3 sec. Approximately 50-80 sec after the injection, the cuff was deflated. Occlusion of one leg was performed to demonstrate the differential perfusion of the ischemic vs. normal leg. The release of the occlusion gives a hyperemic response which is potentially a better, more sensitive measure of ischemia. To calculate a quantitative measure of perfusion, arterial signal intensity curves were taken from the upper slices of the 3D volumetric data. This signal was deconvolved from the temporal muscle signal intensity curves to obtain the impulse responses of the perfusion. Since the deconvolution of digital signals is not unique, a priori knowledge that the perfusion response should be positive and smooth was incorporated by using the quadratic programming method. Then, the first moment of the impulse response was divided by the zeroth moment to get a value function that indicates perfusion. The resulting value represents mean delay time which has a unit in sec. This value was calculated for each pixel in the 3D volume and displayed using a color overlay.

Method Experiments were done using a GE 1.5 T whole-body scanner with a maximum gradient amplitude of 40 mT/m and maximum slew rate of 150 mT/m/ms. The spirals trajectory was combined with a gradient recalled echo (GRE) sequence with a flip angle of 90°. Using the proposed fast imaging technique, a 27 x 27 x 28 cm^3 FOV was covered with 2.5 x 2.5 x 8 mm^3 spatial resolution and 2.8 sec temporal resolution.

Result Nine patients known to have PVD with ABI less than 0.9 were scanned. Three of the patients came in for a follow-up scan after approximately 6 months. Figure 1 shows the perfusion impulse response for a normal volunteer (Fig. 1 a) and a patient (Fig. 1 b, c). In Fig. 2, an oblique slice in the z direction from one of the seventy volumetric data sets for a normal volunteer (Fig. 2 a) and a patient with PVD (Fig. 2 b, c) are shown. The color overlaid on the anatomic image represents the perfusion value calculated from the impulse response. Color was overlaid on pixels with mean delay time less than 72.6 sec. The images were spatially filtered with a low-pass filter before calculating the impulse response to reduce noise in the signal intensity curve. It can be clearly seen that the perfusion parameters closely relate to the disease progress of the patient. Eight other patient results clearly showed longer perfusion time constants than the normal volunteer but the ABI index did not correlate exactly with the MRI study result. Since ABI is known to be not so reliable and since it does not give any regional information, this is not an unexpected outcome.

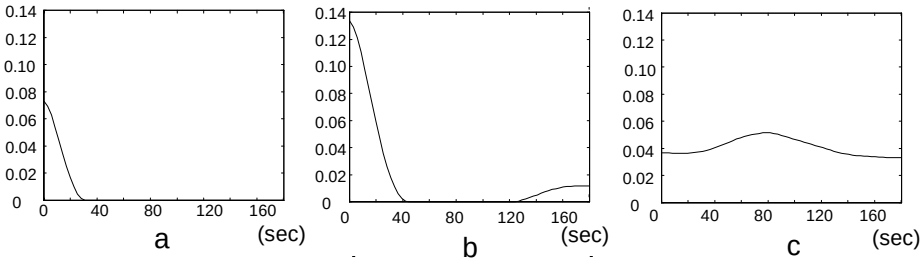

Figure 1 *Impulse response of perfusion for a) a normal volunteer, b) a patient with ABI of 0.6 and c) same patient after 6 months with much worse symptoms of peripheral vascular disease and ABI of 0. The curves were calculated by deconvolving the arterial signal from the muscle signal intensity.*

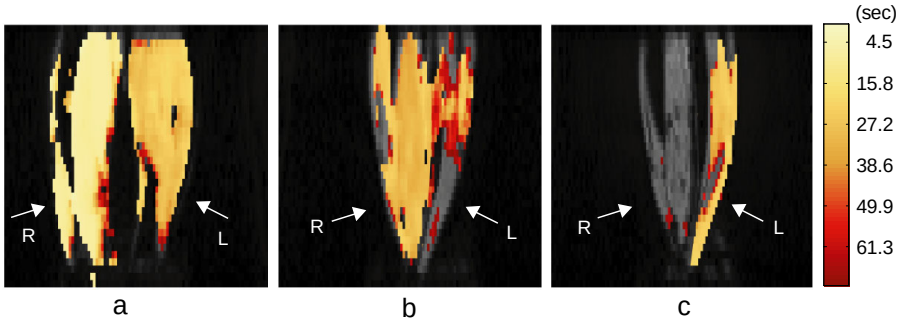

Figure 2 *Average delay time calculated from the impulse response for a) a normal volunteer, b) a patient with ABI of 0.6 and c) the same patient after 6 months with ABI 0. The color overlaid on the anatomic image indicates the average delay time of the perfusion impulse response. The arrows point to the right and left leg respectively. The parameters for the right leg are calculated from the hyperemic response while the parameters for the left leg are calculated from the non-hyperemic response.*

Discussion First-pass perfusion imaging using the proposed technique demonstrates promise in assessing the disease progression in patients with PVD. The volumetric coverage makes this method particularly useful since regional information of perfusion is obtained for the whole lower leg. Higher temporal resolution will help see the upslope of the impulse response. Longer scan periods will be helpful to better resolve the impulse response for patients given the apparent longer perfusion uptake time in patients.

Reference

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