Fast and quantitative imaging of deep vein thrombosis

U. Blume[1], J. Orbell[2], M. Waltham[2], A. Smith[2], K. Burnand[2], R. Razavi[1], and T. Schaeffter[1]

[1]Interdisciplinary Medical Imaging Group, Division of Imaging Science, King's College London, United Kingdom, [2]Academic Department of Surgery, Cardiovascular Division St. Thomas' Hospital, London, United Kingdom

Introduction

MRI has successfully been used for the diagnosis of deep vein thrombosis (DVT) without need for an intravenous contrast agent [1, 2]. An aggregation of red blood cells, which contain methaemoglobin, possesses strong paramagnetic properties resulting in shortening of the T_1 relaxation time and thus an increase of the signal intensity in T_1-weighted images. However, such direct thrombus MR-scans require in unsuitably long scan times of 5 - 10 min. Furthermore, direct visualization of old thrombi is sometimes hampered by prolonged T_1- relaxation times. In this work, fast direct thrombi visualization is combined with quantification using multipoint T_1-mapping [3]. In particular, direct visualization of DVT in lower extremities is possible within 2 min using a 32 channel array coil. A T_1 mapping technique has been applied to suspicious areas, which are detected in the direct thrombi images and obtain quantitative information about the thrombus characteristics.

Methods

The legs of 3 male patients (ages 27, 69, and 70 years) with DVT diagnosed by duplex ultrasonography were imaged on a 1.5 T clinical scanner (Philips Achieva) and using a 32 channel array coil (Philips Research Hamburg) [4]. A magnetization-prepared 3D turbo field echo sequence with a non selective inversion rf-pulse was used for direct thrombus imaging. The image acquisition was ECG-triggered and performed in the end diastole when the flow in the femoral artery is slow [5]. The inversion time is dependant on the heart rate of the patient and was chosen such that that the *k*-space centre was sampled during the null point of blood (T_1 = 1200 ms). Inversion time was determined by simulation of the Bloch-equations. In order to improve contrast fat suppression was performed. The imaging parameters were FOV of 400 x 160 x 245 mm^3, voxel size: 1.25 x 1.25 x 3.5 mm^3, flip angle: 30°, TE = 3.0 ms and multiple gradient echo acquisitions (32) with a repetition time of TR = 6.2 ms. The total scan time was 1.44 min with a SENSE factor of 2 in the AP direction and a SENSE factor of 2 in the FH direction (R = 4). After imaging the thrombus, the acquired dataset was used to plan a 3D multipoint T_1 mapping sequence (Look-Locker sequence) covering the whole thrombus in 10 slices with a thickness of 3 mm using a three-point planning tool. The technique was performed to sample the relaxation curve at 24 time-points for each pixel. Furthermore, a relaxation delay of 4 s after each acquisition was required to ensure magnetization recovery of tissues with long T_1 relaxation times. The other MR parameters were: FOV: 340 x 204 x 30 mm^3, flip angle: 10°, TE = 6.3 ms, 8 readouts with TR = 6.3 ms, SENSE factor of R = 2 (AP). After the acquisition the T_1 value for each pixel was calculated using a 3 parameter fit [6].

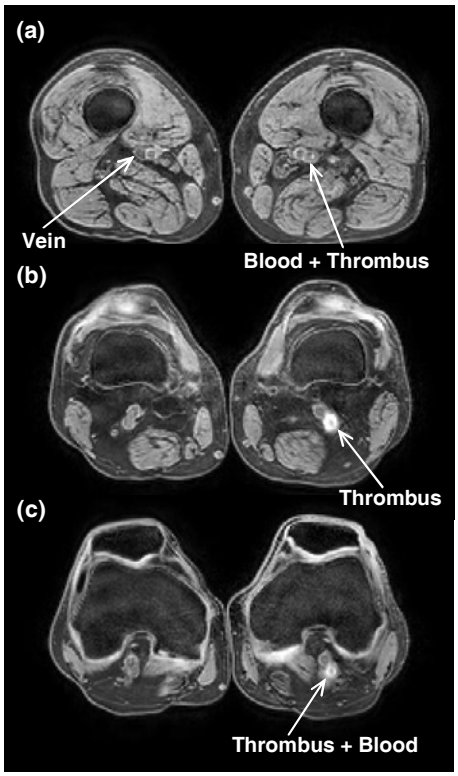

Figure 1: Transverse Slices of T1-weighted 3D dataset taken at different levels through the thrombus.

Results and Discussion

Figure 1 shows three transverse slices of the T_1-weighted 3D dataset of one patient with a thrombus in the left popliteal vein highlighted. The patient had presented with symptoms and diagnosed with a left sided DVT five days before the MRI scan. The signal from blood in the right popliteal vein is suppressed (Fig. 1a) as a result of the inversion time. On the left leg however, the three slices demonstrate varying signal intensities from the blood and the thrombus. A quantitative analysis was performed by the multipoint T_1 mapping measurement (Fig. 2). The R_1-Map ($R_1 = 1/T_1$) in Figure 2B shows the relaxation times distribution. The T_1 value of the blood as measured in the popliteal artery was T_1 = 1422 ± 98 ms. The T_1 values of the thrombus at positions corresponding to the slices in Figure 1 were respectively (a) T_1 = 951 ± 98 ms, (b) T_1 = 591 ± 61 ms, and (c) T_1 = 742 ± 67 ms. The differences in the relaxations times of the thrombus could be explained by different intra-voxel contribution from blood and thrombus in the different slices, which may be an indication of a resolving thrombus. Furthermore, the varying amount of methaemoglobin as thrombus resolves also influences the value of T_1 as shown in previous in vitro studies [7].

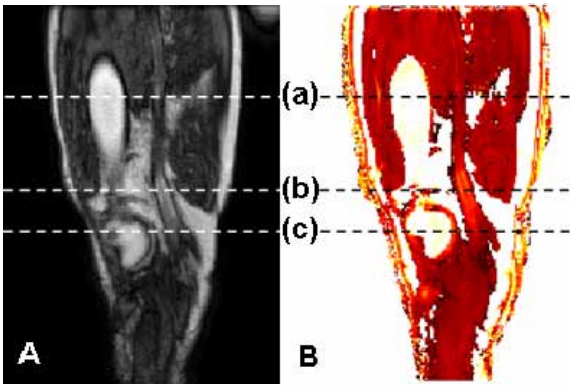

Figure 2: A: slice of magnitude T1-mapping 3D dataset, acquired at TI = 893 ms; B: R1-Map, (a) T_1= 951 ± 98 ms, (b) T_1=591 ± 61 ms, and (c) T_1=742 ± 67 ms at slice positions of Figure 1.

Conclusion

The use of the 32 channel array coil for DVT imaging reduces the total scan time for an ECG-triggered 3D dataset to less than 2 min and also improves image quality compared to scans acquired with a 4-element array coil. Thrombi are highlighted and the venous and arterial blood is suppressed, without any perceptible reduction in SNR. Quantitative analysis shows that the T_1 relaxation times of the thrombus vary depending on the intra-voxel blood to thrombus ratio, which has the potential in providing information about the stage in process of the thrombus resolution.

References

[1] Moody AR, et al, Lancet 350, 1073 (1997); [2] Kelly J, et al, Thromb Haemost 89, 773-782 (2003); [3] Look DC, et al, Rev Sci Instr 41, 250-251 (1970); [4] Schacht-Hansen M, et al, Proc. 14th ISMRM p. 2579 (2006); [5] Klein WM, et al, J Vascular Surgery 38, 1060-1066 (2003); [6] Deichmann R, et al, MRM 42, 206-209 (1999); [7] Rapoport S, et al, Radiology 162, 527-530 (1987)