High-Field MR Venography using Adiabatic T_2 Magnetization Preparation

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Introduction

Highlighting the lumen of veins while attenuating arterial signal in MRI can be of use for several clinical purposes such as guiding the placement of pacemaker leads [1] or the diagnosis of venous thrombi [2]. At a magnetic field strength of 1.5 T, coronary venography has successfully been implemented with magnetization transfer contrast (MTC) [3] prepulses. Unfortunately this approach is too specific absorption rate (SAR)-intensive to be applied at 3 T. For these reasons, we sought to make use of the difference in T2 relaxation time between the venous and arterial blood-pool to obtain images in which the veins are highlighted while the arteries appear signal-attenuated. Since the venous signal is suppressed when a T_2 preparation module ('T2prep') is added to a pulse sequence at 3T, we sought to subtract images obtained with and without an adiabatic T2prep [4] to enhance the contrast between high-T_2 structures such as the arterial lumen blood-pool and veins, with a lower T_2.

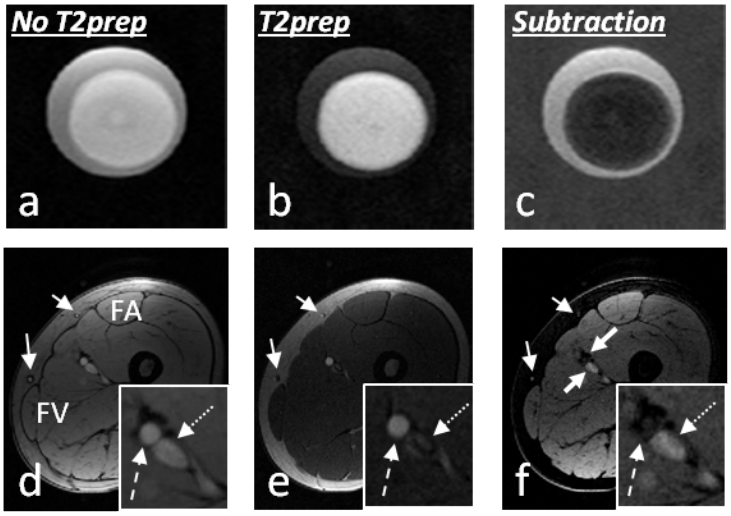

Figure 1: *Demonstration of the T_2 preparation subtraction principle on a chicken egg **(a-c)** and a human upper left leg **(d-f)**. Insets in **d-f** are zoom-ins of the femoral artery (dashed arrows) and femoral vein (dotted arrows). Left images are GRE without T2prep, the middle are GRE with T2prep and the right images their subtraction. **c)** The signal of the higher-T_2 yolk in the center of the egg is significantly suppressed after subtraction. **d)** The femoral artery, femoral vein and superficial veins (solid arrows) are signal enhanced. **e)** Only the artery is visible after T2Prep (see inset). **f)** The arterial signal is suppressed while the vein appears bright.*

Materials and Methods

The study was performed on a 3 T Siemens Trio system with a 32-channel coil and was split into three parts: a phantom test in boiled chicken eggs where the yolk and egg white have a different T_2, a 'non-moving' study in the upper leg (n=2) and finally a 3D free-breathing study of the heart (n=3). All subjects were healthy adults, the study was approved by the local ethics committee and written informed consent was obtained from all subjects. In the egg, a segmented gradient echo (GRE, TE=3.8 ms, TR=8.1 ms, 256x256) sequence was acquired twice, once with an adiabatic T2prep turned on (echo time TE of 50 ms) and once with the module turned off. The T2prep consisted of a +90° hard pulse, two 12 ms hyperbolic secant adiabatic pulses to refocus the transverse magnetization while undergoing T2 decay and a -90° hard tipup pulse. In the upper leg the same methodology was used. In the heart, a 3D whole-heart volume was acquired ECG-triggered with and without T2prep (TE=50 ms) with a segmented k-space GRE imaging sequence (TE=2.04 ms, TR=4.68 ms, 320x208x160 mm^3, 256x166x88 resolution, total acquisition time ~15 min) that was preceded by a real-time navigator for respiratory motion suppression and the adiabatic T2prep for contrast generation. All images were subtracted after normalization to the highest signal-intensity value.

Results and Discussion

After signal attenuation of the shorter-T_2 egg white by the T_2 preparation module (Fig. 1b), the subtraction of the two images obtained with and without T2prep resulted in an effective signal suppression of the yolk with the longer T_2 (Fig. 1c). Consistent with these findings, the femoral artery in the upper leg appeared signal-suppressed (insets Fig. 1d-f) thereby enabling the unambiguous identification of the adjacent signal-enhanced femoral vein (Fig. 1f). It should be noted though, that this increase in contrast comes at the expense of a doubled acquisition time. It can also be observed that the fat signal is effectively suppressed in the subtracted image, causing several superficial veins (SV) to stand out. Muscle tissue, which has a T_2 in-between that of venous and arterial blood and which also appears signal-suppressed after T2prep, has moderate signal intensity in the subtracted image. Similar results can be seen at two different anatomical levels of a 3D cardiac dataset (Fig. 2). The great cardiac vein and azygos vein display with enhanced contrast (Fig. 2c), while both the coronary sinus and azygos vein also appear signal enhanced on a more mid-ventricular level (Fig. 2f). Overall we conclude that at the expense of a 2-fold increase in scanning time, this technique enables contrast enhancement between the venous blood-pool and the surrounding anatomical structures including arterial blood, while SAR limitations at higher field strength can successfully be avoided.

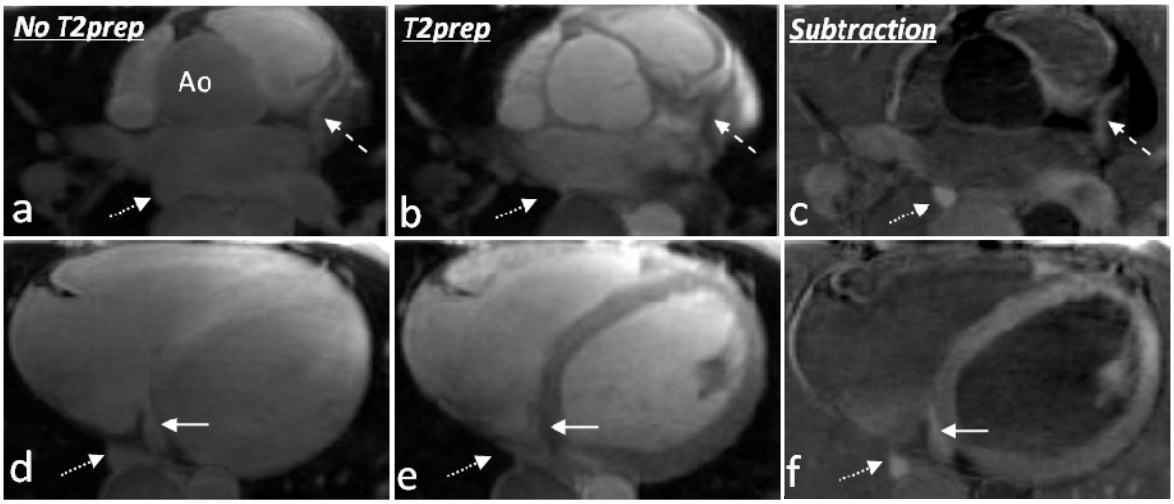

Figure 2: *Zoom-in of an axial slice from a basal **(a-c)** and a mid-ventricular **(d-f)** level in the heart of a healthy adult subject. The middle images with adiabatic T2prep **(b,e)** are again subtracted from those on the left obtained without T2prep **(a,d)** to obtain the images on the right **(c,f)**. Several veins are indicated with arrows: the great cardiac vein (dashed arrow in c) and the azygos vein (dotted arrows in c & f). The coronary sinus can be seen at a mid-ventricular level (solid arrow in f).*

References: 1. F Yang and R Patterson, Ann Biomed Eng 36(10):p1659 (2008) **2.** A Ono et al., Magn Res Med 64:p88 (2010) **3.** CT Stoeck et al., Magn Reson Med DOI 10.1002/mrm.22581 (2010) **4.** R Nezafat et al., Magn Reson Med 61:p1326 (2009)