High-Field MR Venography using Adiabatic \text{T}_2 \text{ Magnetization Preparation}

R. B. van Heeswijk, S. Coppo, T. Kober, and M. Stuber

1Department of Radiology, Centre Hospitalier Universitaire Vaudois and University of Lausanne, Lausanne, Switzerland, 2Center for Biomedical Imaging (CIBM), Lausanne, Switzerland, 3Advanced Clinical Imaging Technology, Siemens Suisse SA - CIBM, Lausanne, Switzerland

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] prepsules. 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 \text{T}_2 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 \text{T}_2 preparation module (‘\text{T}_2\text{prep}’) is added to a pulse sequence at 3T, we sought to subtract images obtained with and without an adiabatic \text{T}_2\text{prep} [4] to enhance the contrast between high-\text{T}_2 structures such as the arterial lumen blood-pool and veins, with a lower \text{T}_2.

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 \text{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 \text{T}_2\text{prep} turned on (echo time \text{TE} of 50 ms) and once with the module turned off. The \text{T}_2\text{prep} consisted of a +90° hard pulse, two 12 ms hyperbolic secant adiabatic pulses to refocus the transverse magnetization while undergoing \text{T}_2 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 \text{T}_2\text{prep} (TE=50 ms) with a segmented k-space GRE imaging sequence (TE=2.04 ms, TR=4.68 ms, 320x208x166 mm³, 256x166x88 resolution, total acquisition time ~15 min) that was preceded by a real-time navigator for respiratory motion suppression and the adiabatic \text{T}_2\text{prep} for contrast generation. All images were subtracted after normalization to the highest signal-intensity value.

Results and Discussion

After signal attenuation of the shorter-\text{T}_2 egg white by the \text{T}_2\text{prep} preparation module (Fig. 1b), the subtraction of the two images obtained with and without \text{T}_2\text{prep} resulted in an effective signal suppression of the yolk with the longer \text{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 \text{T}_2 in-between that of venous and arterial blood and which also appears signal-suppressed after \text{T}_2\text{prep}, 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.