Low SAR body transmit facilitates ^{31}P multi-echo spectroscopic imaging in the human body

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Introduction. X-nuclei MRSI in the human body is generally restricted to small volumes as conventional surface coils are being used. Consequently, high energetic adiabatic pulses are required for homogenous excitation in the limited region of interest, greatly increasing SAR. Löring et al. showed a ^{31}P whole body birdcage coil allowing uniform B_1^+ fields in the torso potentially avoiding the need for adiabatic RF pulses.[1] In addition, van der Kemp et al. showed a novel 3D ^{31}P multi-echo MRSI method (MESING) in the brain, enabling T_2 measurements.[2] Here, we demonstrate feasibility of the ^{31}P MESING in the human body, using a ^{31}P body coil and local receiver coil at 7 tesla.

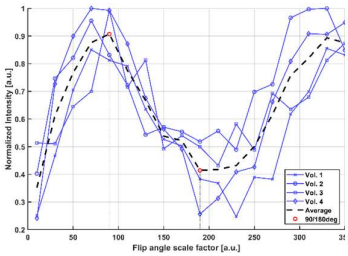

Figure 1. Summary of the *in vivo* B_1^+ calibration of the ^{31}P body coil from four volunteers.

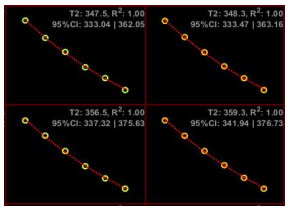

Figure 2. *In vitro* T_2 measurement of Pi from the torso-like phantom. Maximum peak values are denoted as open circles and the fit is represented as a red dotted line.

Methods. ^{31}P MRSI was performed using a 7T MRI system (Philips Healthcare, Best, Netherlands) in combination with a permanently integrated custom built whole body birdcage coil driven by a 25kW amplifier. A dual Rx ^{31}P array was used for acquisition in combination with two fractionated dipole antennas in quadrature mode for proton MRI, enabling localization and imaged based B_0 shimming. *Ex vivo* measurements were performed on a torso-like phantom that included inorganic phosphate (Pi). Four volunteers were positioned in prone position and the receive array was positioned on the gluteal muscles. The B_1 field was calibrated in all volunteers with a flip angle series. MESING was applied in a single volunteer with an isotropic resolution of 40mm and a single FID with five echoes were acquired. Other parameters were TR, 5s; ΔTE, 45ms; Matrix, 8x8x6; BW, 7800Hz; #Samples, 256 and a scan duration of 21:20min. All MRSI protocols only used rectangular block pulses. T_2 values were calculated by fitting a mono-exponential model to the maximum peak intensity of Pi (*ex vivo*) or PCr (*in vivo*) using the levenberg-marquardt algorithm in Matlab 2017b.

Results. The ^{31}P B_1^+ calibration curve shows a sinusoidal excitation profile and is very consistent over all volunteers with only minor variations (Fig. 1). The 180 degree composite block was 4.26ms, which compared to a hypothetical power optimized adiabatic pulse at identical B_1 level, corresponds to a ~4.5-fold reduced effective B_1 integral. The average T_2 of Pi in the phantom is 355ms (Fig. 2). The average T_2 of PCr in gluteal muscles is 132ms. (Fig. 3)

Discussion. We successfully implemented the MESING method in the torso using the ^{31}P body coil at 7T. Using rectangular versus adiabatic RF pulses favors overall SAR allowing for increased number of pulses per scan time. Validation of T_2 of Pi in the phantom agreed with measurements using a conventional setup. T_2 of PCr in the gluteal muscle (132ms) is lower than reported values in the calf muscle (192ms).[3] This can be caused by physiological difference or sub-optimal refocusing pulses. When compared to short TR Ernst angle excitation schemes, the bandwidth of MESING with the 25kW body coil is still low, requiring further investigation in for instance multiband RF pulses to allow full spectral coverage. Moreover, the two channel receiver may benefit from a full body array to extend the FOV to the entire body.[4]

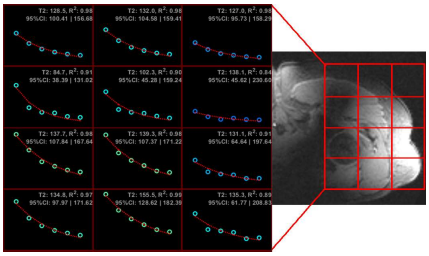

Figure 3. (**A.**) *In vivo* T_2 measurement of PCr located in the gluteal muscles as annotated by the red grid in (**B.**) the T1-weighted localizer image. Maximum peak values are denoted as open circles and the fit is represented as a red dotted line.

Conclusion. Low SAR 3D ^{31}P multi-echo MRSI at 7T MRI is feasible in the human body using only rectangular block pulses.

References **1)** NMR Biomed, 2016;10.1002/nbm.3517 **2)** MRM, 2018 10.1002/mrm.27026 **3)** NMR Biomed, 2013;10.1002/nbm.2952 **4)** PloS ONE, 2017;10.1371/journal.pone.0187153