^{31}P Birdcage insert for an 8-channel, multi-transmit, ^{1}H coil at 7T

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Purpose: Direct insight in metabolic processes, like energy metabolism or cell membrane turnover, can be obtained by ^{31}P magnetic resonance spectroscopic imaging (MRSI). Although the sensitivity of this nucleus is significantly higher at higher magnetic field strengths (≥7T), dedicated hardware is needed to acquire signals at the resonance frequency of ^{31}P compounds, but also at the ^{1}H frequency for anatomical imaging, B_0- and B_1-shimming, and for spatially homogeneous decoupling and/or ^{31}P signal enhancement with Nuclear Overhauser Effect (NOE). We designed and constructed a ^{31}P birdcage coil (BC) as an insert for an 8-channel, multi-transmit, octogonal shaped, ^{1}H coil [1] to enable homogeneous excitation and acquisition of ^{31}P signals combined with the above-mentioned ^{1}H applications.

Materials and methods: A high-pass BC was created with copper foil (width 1.25cm) attached to a plexiglass tube (Øout: 25cm, length: 25cm, thk: 0.5cm). Eight rungs (length: 15.5cm, width: 5mm) were positioned between the eight ^{1}H microstripline elements with meanders (fig. 1). The BC was tuned to 120.3MHz using 15pF capacitors (determined with Birdcage builder [2]). At both ends of each rung a tank circuit tuned to 297MHz was positioned to decrease coupling between both coils. Simulations (CST Studio Suite, CST, Darmstadt, Germany) of the complete setup were performed to assess homogeneity of the ^{1}H-field and to locate couplings between both coils. In a phantom experiment the ^{1}H B_1-distribution was validated and the ^{31}P homogeneity was evaluated. To assess the functionality of both coils (^{1}H multi-transmit capabilities & ^{31}P + enhancement) we examined both calf muscles of a single volunteer (M, 30y) simultaneously. After ^{1}H B_1- & B_0-shimming and flip angle calibration, we obtained a T_1-weighted TSE (TR/TE/TI: 600/18/100ms, turbofactor/shots: 9/36, Tacq: 29s) and a 3D GRE with fat saturation (TR/TE: 32/5ms, flip: 15°, Tacq: 120s). After ^{31}P flip angle calibration, 2D pulse-acquire MRSI was acquired to assess local differences in metabolite concentrations (TR: 1500ms, FOV: 25x200x250mm, voxel size: 12.5x12.5mm, flip: 45° (block pulse), Tacq: 470s, fig. 4C). Additionally, we performed two MRSI examinations at lower resolution, once with NOE using low-power continuous wave ^{1}H irradiation on water to enhance the ^{31}P signals, and once without NOE (TR: 1120ms, FOV: 25x200x250mm, voxel size: 20x21mm, flip: 35° (block pulse), Tacq: 220s).

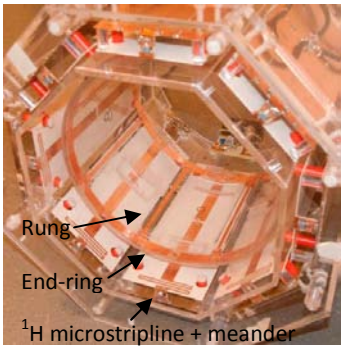

Figure 1: The ^{31}P birdcage coil inside the octagonal shaped 8-channel ^{1}H coil, with the rungs positioned between the microstripline elements.

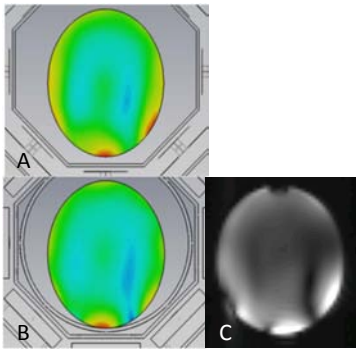

Figure 2: Simulated and measured $|B_1^+|$ distribution, with (B) and without (A) ^{31}P BC insert. (C) B_1-map obtained from same phantom with ^{31}P BC insert.

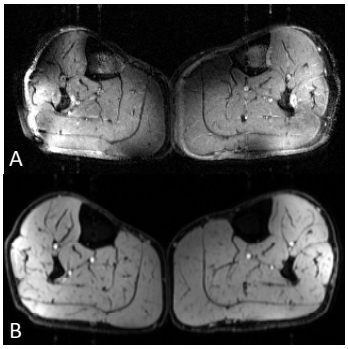

Figure 3: 1H-images obtained with the 8 channel coil:
(A) TSE image
(B) 3D GRE with fat saturation.

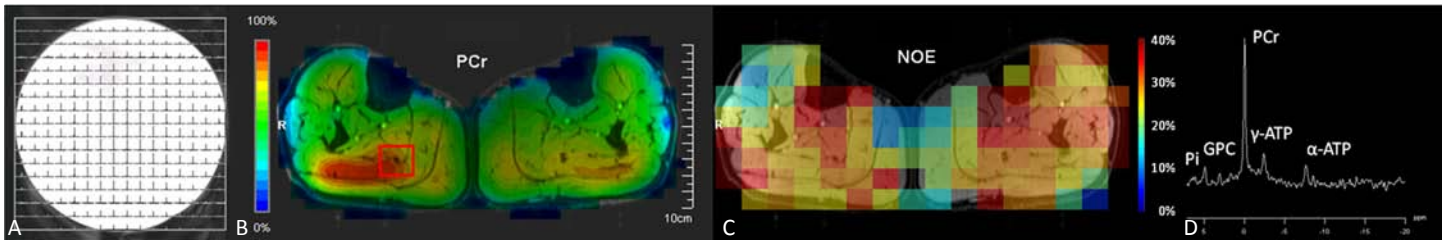

Figure 4: Examinations performed with the 31P-birdcage coil. (A) spectral map of inorganic phosphate (Pi) showing ^{31}P homogeneity in a phantom, (B) metabolic map of PCr signal in both calf muscles of a healthy volunteer, (C) NOE-enhancement map, (D) typical ^{31}P spectrum from voxel indicated in B. Glycerophosphocholine (GPC).

Results and discussion: Simulations of the magnitude of the B_1^+-field in CP^+-mode show similar patterns in the ^{1}H field with and without the 31P BC insert present (fig. 2), indicating minimal coupling between both coils. B_1-shimming could be performed with the BC inserted into the 8-channel coil, homogenizing flip angles over both legs, shown by the fairly homogeneous T_{1w} TSE images (fig 3A). Outstanding anatomical muscle delineation was achieved with additional GRE images (fig. 3B). As homogeneous excitation was achieved with the ^{31}P BC (fig. 4A) differences in phosphocreatine (PCr) between separate calf muscles could be visualized (fig. 4B). B_1-shimming enabled homogeneous NOE enhancement of the PCr-signal, the enhancement was determined to be 28 ± 5% for both legs (fig. 4C). A typical ^{31}P muscle spectrum is shown in fig 4D.

Conclusion: We succesfully designed, validated and constructed an 8 rung, highpass, ^{31}P birdcage as an insert for an 8-channel, octogonal shaped, multi-transmit, ^{1}H coil, combining homogeneous ^{31}P excitation and acquisition with ^{1}H multi-transmit capabilities to assess metabolic processes *in-vivo* at 7T.

References: [1] Orzada *et al.* Proc. ISMRM 17 (2009) #3010, [2] Chin *et al.*, Birdcage builder v1.0 (1998)