A 16 Channel Cardiac Array for Accelerated Hyperpolarised 13C Metabolic Imaging on Pigs at 3T

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Target audience: 13C community and RF coil design

Purpose: Multi-channel receive coils are well established in 1H applications since decades [1]. However, coil arrays for other nuclei are fairly uncommon. The main reason is that multi-channel Rx hardware for nuclei other than 1H was not available on clinical scanners for a long time. Even if nowadays the hardware is getting more common, the reconstruction for multi-channel data for other nuclei is still non-standard and involved due to low SNR and other limitations. Hyperpolarisation methods drastically improve SNR and hence enable multi-channel data acquisition. Imaging of hyperpolarised substances requires low RF application since the available magnetisation M0 is limited and not replenishing. This makes array technology with the ability of accelerated imaging interesting and necessary. The purpose of this work was to design a 16-channel receive coil for metabolic imaging with hyperpolarised 13C substances in the pig heart. The needs were to improve the SNR of the heretofore used Tx-Rx-volume coil with a local receive coil as well as to enable parallel imaging for 13C. The final goal is to evaluate the possibility of transferring the technique to human subjects.

Methods

The receive (Rx) coil is derived from a flexible 1H array for humans and is composed of 16 elements resonating at 32.1 MHz (13C frequency at 3 T). Each element has a size of 5 x 8 cm2 with a conductor width of 2 mm. Symmetric coupling schemes including cable traps were used for fixed tuning and matching (Fig. 1). Active decoupling was done by PIN diodes and 13C traps, passive 1H traps were used for decoupling from the 1H body coil. In order to evaluate the potential performance in human application, all safety mechanisms like passive PIN diode traps and fuses were included, even if these mean a lower Q and, therefore, lower overall SNR. Preamplifier decoupling was done by transforming the high S11 of the preamplifier input to a high impedance in the coil circuit by phase shifters. Neighbouring elements were decoupled by overlap, resulting in a total array size of 19 x 26 cm^2. The 4x4 array is made from flexible printed circuit board, "baked" into PE foam in order to accomplish high flexibility. The final array is shown in Fig. 2. The setup (Fig. 3 with pig) was designed for a 3T GE HDx MR system. The Tx resonator is a 13C birdcage with an inner diameter of 35 cm and a length of 36 cm. It contains no RF shield but 1H traps for allowing 1H imaging with the body coil. It is actively decoupled by PIN diodes in each leg.

Metabolic imaging on 13C was shown by injecting 0.13 mmol/kg body weight [1-13C]pyruvate solution into a healthy male farm pig (25 kg) [2]. For fast CSI encoding, a spiral CSI sequence was used with 3 echo time delay and 4 spatial interleaves [3].

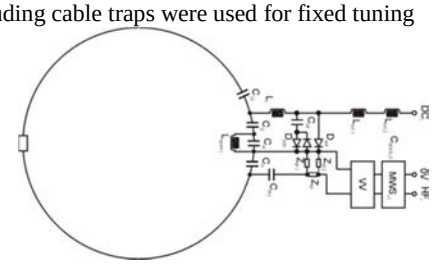

Fig. 1: Electrical circuitry of a single coil element, including tune, Match, active and passive detuning, fuse, preamplifier (VV) and cable trap (MWS).

Fig. 2: The housing of the flexible Rx array has a total size of 23 x 40 cm^2.

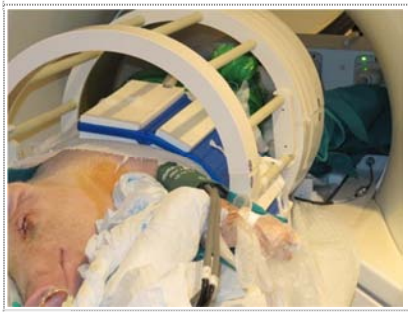

Fig. 3: Setup including the Tx birdcage and the Rx array on a 25 kg pig.

Results and Discussion

The Tx coil is tuned and matched manually, achieving a S11 and a S12 of better than -20 dB. Average S11 of all Rx elements was -22 dB. Ratio of unloaded to loaded Q was 135 / 98 = 1.4, displaying the coil noise dominance. This effect is due to the low frequency combined with small coil element size while having additional 1H traps. Since the setup was made especially for accelerated imaging on hyperpolarised media, an array with low Q drop still makes sense. In addition, due to the far better filling factor, there is essential SNR gain as compared to the transmit-receive whole-body birdcage coil used before (data not shown). Mean S12 of neighbouring elements of the array was -17 dB. The worst S12 of non-neighbouring elements of -8.6 dB was compensated by the preamplifier decoupling. The sufficient functioning of this decoupling is shown in the noise correlation which was obtained by a noise scan (max 40%, mean 27%, min 10%). Metabolic images of the left ventricle *in vivo* in short axis view are shown in Fig. 4. The different metabolites can nicely be located within the heart muscle.

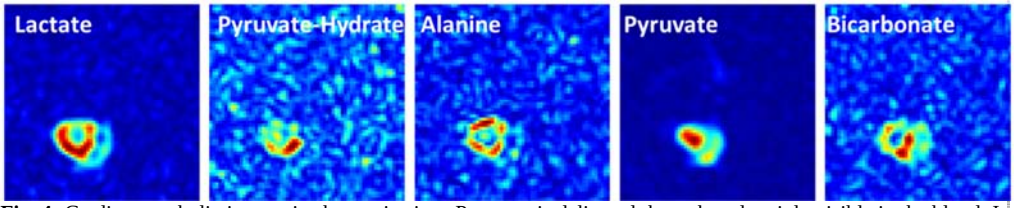

Fig. 4: Cardiac metabolic images in short axis view. Pyruvate is delivered through and mainly visible in the blood. It gets converted in the myocardium into lactate, alanine and bi-carbonate. Mainly the thick (~8mm) left myocardium is visible; because of high SNR with this coil also parts of the thin (1-2mm) right myocardium are visible.

Conclusion

We developed a coil and showed a setup for 13C metabolic imaging on hyperpolarised media in pigs on a clinical 3T system. Due to the low frequency of 32 MHz, the Rx array is still coil noise dominated, which was enforced by the need of 1H imaging with the body coil and the safety mechanisms necessary for potential human application. The setup allows accelerated 13C imaging which is essential for efficient usage of the hyperpolarised magnetisation. First results on the pig heart are shown. Future work will be the optimisation of the sequence and time resolved application of the setup, investigating the metabolism.

References

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