Construction of a 4-Channel Transmit Neck Array for pCASL Tagging at 7 Tesla and Comparison with a Head Coil.

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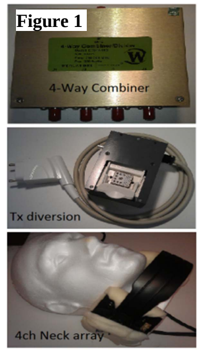
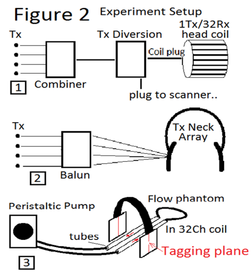
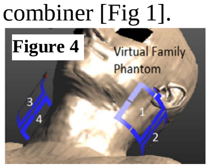
Target Audience: In this study, a custom-designed arterial spin labelling RF coil was assessed for its efficiency and safety, and thus is of particular interest to ultra high field MRI scientists working on RF coil design and parallel transmission (pTx).

Purpose: RF coils at 7T can be designed to mitigate B_1 field inhomogeneity but the most effective solution to RF inhomogeneity is to use parallel transmission. However, such a setup may compromise the safety of the subject through excessive RF heating. In this study, a variant of the pseudo continuous arterial spin labelling (pCASL) [1] sequence was implemented on a Siemens 7T scanner with 8 independent power-supervised Tx channels. A comparison of tagging efficiency and RF heating deposition was made between tagging with a custom built 4-channel Tx neck array versus tagging with a commercial single transmit channel 1Tx/32 Rx volume head coil (Nova Medical, Wilmington, MA).

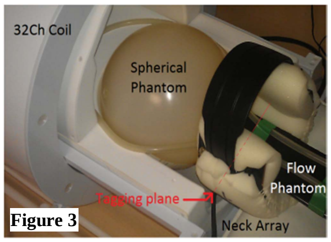


Methods: A 4-channel neck array was constructed using two pairs of loops placed at each side of the neck, held together with a flexible cradle [Fig 1]. For each coil, a pair of accessible variable capacitors was used for fine tuning and matching and the channels were tuned/matched at 297.2MHz and ≤ -20dB. In order to use both the 32ch coil and the transmit labelling array, a special setup [Figs 2 & 3] was necessary to overcome scanner restrictions. A 4-way combiner was used to combine the power of four of the available pTx channels and a switching arrangement used to divert the Tx channel of the 32Ch coil to the combiner [Fig 1].





SEMCAD X (SPEAG, Zurich) software was used for electromagnetic characterisation of the coil in conjunction with a human phantom [3] [Fig 4]. E and B1+ fields per volt per channel were calculated for each of the 4 elements and were then processed with MATLAB for estimation of relative amplitudes and phases for RF shimming around the carotid arteries [Fig 5]. The transmission power limit per channel was set to be the worst case scenario, which is the phase combination that results in the maximum generated SAR [4]. The SAR is calculated over 10g mass cubes, averaged according to the IEEE/IEC 62704-1 standard [Fig 6].



Finally, ASL tagging efficiency was measured experimentally using two flowing tubes with a pCASL prepared FLASH sequence. A spherical phantom was used to load the head coil and a cylindrical phantom used to load the neck coil [Fig 3]. The mean velocity of the flowing water was 12.5 cm/s in a 4mm diameter tube. A flow compensated FLASH acquisition was prescribed with the phase encode direction perpendicular to the flow, and with FOV 200mm, 25% phase encode FOV, slice thickness=5mm, 192x48 matrix, TR=3sec, TE=3.1ms. A 400ms pCASL pulse train preceded each excitation with 0.6ms RF pulses, 1060ms separation, tag gradient 6mT/m, mean gradient 0.8mT/m and 10ms post label delay. Tagging was performed with the neck and head coils and the tagging efficiency was measured by taking the complex subtraction of the tag and control images after phase unwrapping using PRELUDE (FSL, Oxford) [5] and after normalising to an M_0 image with the tagging pulse voltage set to zero.

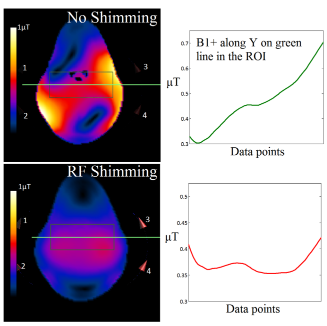


Figure 5: B1+ field normalised at 1Watt per Ch Shimmed and Unshimmed condition and field variation along Y in the middle of the ROI

Results & Discussion: Simulations: In the RF unshimmed condition the anterior/posterior variation in the middle of the ROI is ±0.2μT around the mean and $B1_{max}/B1_{min}$=2.3 whereas in the shimmed condition a ±0.05μT variation around the mean was achieved with $B1_{max}/B1_{min}$=1.2 [Fig 5]. The worst case scenario, as defined in the Methods section, generated a maximum local SAR of 2.87W/kg for 1 Watt per channel input [Fig 6]. Thus, for 1st level control (20W/kg max [6]), the power scale factor is 7 per channel. In the shimmed condition with optimized amplitude and phase variation the max 10g SAR was 2.2W/kg.

Phantom Experiments: The effective global SAR of the affected body parts (head, neck & shoulders represented by the spherical and cylindrical phantoms) was calculated from the known power transmitted to the RF coils (and accounting for the 8% duty cycle used in the sequence). During tagging with the 32Ch coil the highest estimated global SAR was 1.98W/kg and the mean ASL tagging efficiency was just over 31%. When the neck coil was used for tagging the highest estimated global and local SAR was 2.5W/kg and 7.3W/kg, respectively, and the tagging efficiency was improved to approximately 72% [Fig 7 & Table 1].

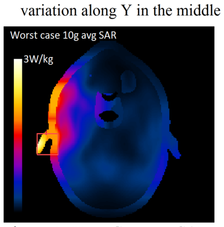


Figure 6: Worst Case 10g SAR is at 2.87W/Kg

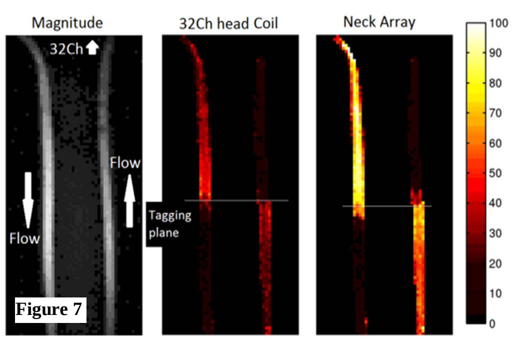


Table 1: Tagging Efficiency and SAR [W/kg]

Coil	Left Tube	Right Tube	Combined	SAR%
32Ch	34.1 ± 6.8 %	27.2 ± 4.5 %	31.3 ± 6.9 %	61%
Neck	80.2 ± 13 %	59.5 ± 6.3 %	71.9 ± 15 %	78%

Conclusion: For the same power output, the neck coil provided more than double the tagging efficiency albeit with a 27% SAR increase in comparison to the 32Ch head coil. As long as local SAR and power transmission are supervised in total and per channel it is preferable to use local tagging for ASL at 7T. Human scanning is being conducted to further investigate the benefits from local tagging.

References: [1] Tom Okell DPhil Thesis, Oxford University. [2] Mispelter J et al. NMR Probeheads, London 2009. [3] Christ A *et al*, *Phys. Med. Biol.* 55, N23, 2010, 2011 [4]Eichfelder G and Gebhardt M, Mag. Res. Med. 1476, 1468-1476, 2011. [5] S. M. Smith et al. NeuroImage 23(S1):208-19, 2004. [6] IEC, Medical Electrical Equipment, 60601-2-33, 2010