A setup for continuous arterial spin labeling with a 4 channel radiative labeling coil allowing for high duty cycle labeling at 7T

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Introduction: The use of external labeling coils for arterial spin labeling (ASL) may increase the effectiveness of different ASL techniques when used at high field MRI. Continous ASL (cASL) is shown to result in better SNR of the Cerebral Blood Flow (CBF) as compared to pulsed ASL since larger volumes of blood can be labeled. However, when going to higher field strengths (> 3T) specific absorption rate (SAR) becomes a limiting factor for the duration of the long labeling pulses. At 7T no body coil is available, and transmission in the head is usually performed using a more tight fitting volume birdcage coil (fig 3). Especially when labeling takes place in lower regions of the head, the B_1^+ efficiency (B_1^+/power) of such volume coils is lower, causing a high SAR. This eventually results in restriction of the allowed label durations, which strongly compromises the CBF signal. The potential gain of external labeling with cASL is twofold: 1) increased B_1^+ efficiency at the labeling slice reduces the SAR and 2) assuming the limited range of the external labeling coil avoids MT effect, no RF power is needed during the control experiment, which reduces the SAR more or less by a factor 2, depending on the T_R used. Also for pulsed ASL (pASL) external labeling may benefit the acquisitions: larger volumes can be labeled at once, and CBF may be measured in lower slices in the head, whereas a head coil alone does not have sufficient coverage for labeling. Here we present a setup for ASL where radiative antenna's are used for external labeling at 7T. SAR simulations are used to show that B1/SAR efficiency is sufficient to allow for high label durations.

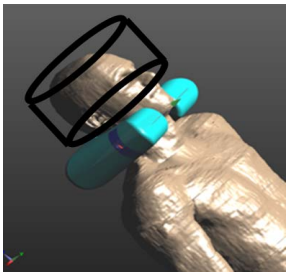

Fig 1 SEMCAD overview of neck array with headcoil

Fig 2, 4 channel transmit array for the neck

Fig 3 experimental setup with combined head coil and neck array

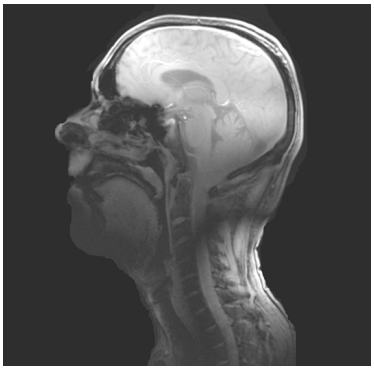

Fig 4 overview image acquired with the combined setup showing the large coverage by the coils

Materials and methods: A birdcage Volume T/R Headcoil (Nova Medical Systems) was used in combination with a 4 channel neck array (fig3), consisting of a neck pillow filled (fig 2) with D_2O, acting as a dielectric waveguide which facilitates a traveling wave approach [1]. The traveling wave modes are fed by radiative antenna's [2]. Each antenna was driven by 2kW peak power. A 16 channel receiver array was used inside the head coil, and the neck array was used in combination with a 15 channel small element receive array [1]. Sagittal gradient echo images were acquired to visualize coverage. AFI B_1^+ maps [3] were acquired in the neck ($T_{R\ ½}$ = 40/160ms, fa_{nom} = 50°). With these maps B_1^+/power was calculated at the height of the carotids. Simulations were performed (SEMCAD X64 v14.2, Speag, Zurich, Switzerland) on the human male model from the Duke family to obtain maximum values in SAR_{10g} ($W{\cdot}kg^{-1}{\cdot}W^{-1}$). With these numbers the maximum heating for a 2µT continuous labelling pulse (100 % duty cycle) was calculated. Based on a maximum allowed SAR_{10g} of 10 $W{\cdot}kg^{-1}$, the maximum allowed duty cycle (and labelling duration for T_R = 5sec) was calculated. The same procedure was applied when using the head coil only.

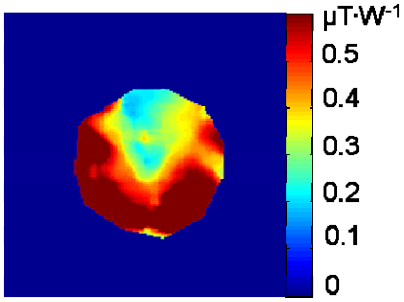

Fig 5 in-vivo transverse B1+ map of the neck using the 4 channel transmit array. The maximum colorscaling for 0.6 µT·W^{-1} corresponds to 18µT using 900W peak power at the antenna

Results and Discussion: Figure 4 shows the sagittal overview image acquired with the setup shown in figure 3. Figure 5 shows the normalized B_1^+ per Watt input power at the antenna. The used RF shim was aimed at homogenizing the B_1^+ field in the entire neck. Focusing the RF power at both carotids only may result in higher B_1^+/power. When using a 2µT continuous pulse (100% duty cycle) the maximum SAR_{10g} was found to be 48.8 and 224 $W{\cdot}kg^{-1}$ for the neck coil and the head coil respectively (see table 1). Limited in the neck to a maximum allowed 10 $W{\cdot}kg^{-1}$ and 8 $W{\cdot}kg^{-1}$ for the head, this results in a maximum duty cycle of 20% and 3.6 % respectively. For T_R = 5sec, this comes down to a maximum label duration of 1000ms for the neck coil and 180ms for the head coil. When no RF power is used during the control experiment (if MT effects can be neglected) the neck coil can label for 2000ms, since the SAR_{10g} is averaged over a period of 10s.

	Neck Array	Head coil
B_1^+/power (µT·W^{-1})	0.4*	0.1*
max local SAR_{10g} ($W{\cdot}kg^{-1}{\cdot}W^{-1}$)	1.95	0.56
max local SAR_{10g} – 2µT continuous ($W{\cdot}kg^{-1}$)	48.8	224
max duty cycle within SAR limit	20 %	3.6 %
max allowed label duration (T_R = 5 sec)	**1000 ms**	**180 ms**
if no RF during control	**2000 ms**	-

* *B_1^+ efficiency at the height of jaws*

Tabel 1 SAR values

Conclusion: A setup was presented for ASL with external labelling at 7T MRI. Labelling pulse of 2000ms duration for 2µT amplitude can be achieved without exceeding the SAR safety guidelines.

Acknowledgments This research was supported by the Center for Translational Molecular Medicine and the Netherlands Heart Foundation (PARISk).

References: [1] Koning et al. Proc Intl Soc Mag Reson Med 19 (2011) #327, [2] Raaijmakers et al. (2011). MRM 66: 1488-1497, [3] Yarnykh (2007). Magn Reson Med 57: 192-200