DC-CASL based Quantitative Brain Perfusion Study with a Portable RF Transmitter System

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Purpose: Among all kinds of arterial spin labeling (ASL) techniques for multi-slice perfusion imaging, Continuous ASL with a separate coil (or Dual-coil CASL) has been proven to have the best SNR with eliminated magnetic transfer interference [1,2]. However, Most implementations of Dual-Coil CASL(DC-CASL) in previous reports require two independent sets of proton RF channel and amplifier, which are not currently available on most clinical MRI scanners[2~4]. Although several methods have been proposed to build up DC-CASL easier, either using the original scanner RF channel by inserting a high-power RF switch between the scanner RF power amplifier and the coil system or by designing a complicated PCI card to generate the RF signal[5,6], none of them is widely accepted yet. In this study, a portable RF transmitter, which is based on a single chip microcomputer (SCM) plus Direct Digital Synthesizer (DDS) structure, designed and tested for non-invasive perfusion imaging in clinic.

Material and Method

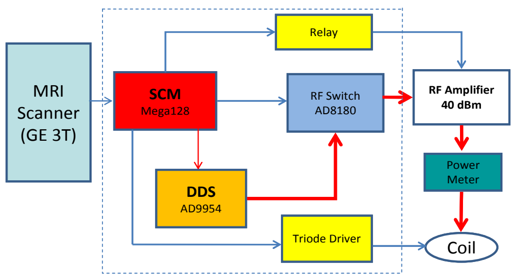

Figure 1 Hardware diagram of the portable CASL RF transmitter

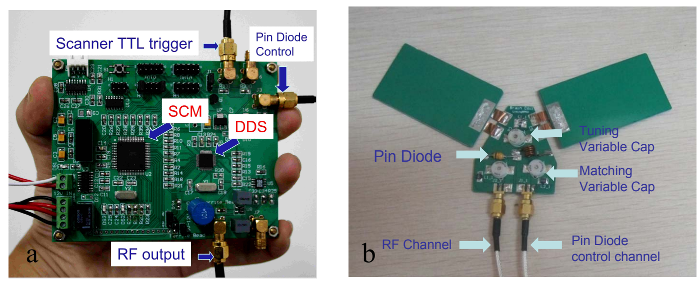

Figure 2 (a) Photograph of the RF transmitter (b) Photograph of the Butter-fly labeling coil

2.1 CASL RF transmitter system design: As shown in Fig 1, a SCM Mega128 (TI crop., Texas, USA) is used here to monitor the MRI triggering TTL signal and drive the DDS AD9954 (Analog Devices, Norwood, MA) to generalize the required radio frequency (RF) signal synchronously. The RF signal is then delivered through a 40 dBm minimized power amplifier(Lattok corp., Beijing ,CHN) to a actively detuneable butterfly labeling coil, which is placed on the neck of the subjects to inverse the flowing blood based on the principle of fast passage adiabatic inversion . A relay and a Triode driver are employed to cutoff the power of the RF amplifier and detune the labeling coil synchronized to the time sequence of the CASL, respectively. The gain of the minimized RF power amplifier is adjustable and a power meter (SX-600, Diamond corp., San Marcos, CA) is used to monitor the power delivered into the labeling coil. A home made butterfly coil was also built up, each wing of which has a size of 3cm×6cm. The desired labeling frequencies are calculated according to Eq.1.

$$F_{label} = f_0 + \gamma G \Delta z \qquad (1)$$

where f_0 is the central resonance frequency of the 3T scanner; g is the gyromagnetic ratio of proton; G is the labeling gradient, and ⊿z is the distance between center of the labeling slice and iso-center of the scanner .

2.2 Imaging Protocol: During the tagging image period, Adiabatic flow driven RF labeling is achieved by a 2s RF pulse applied simultaneously with a 2.5 mT/m labeling gradient. After a post-labeling delay (PLD) of 700 ms, CASL perfusion MRI data are acquired with a spiral acquisition sequence. During the control period, the labeling coil is detuned and no gradient is applied.

2.3 CBF calculation**:** The raw CASL perfusion data is obtained by subtracting the tag from control brain images. CSF(Cerebral Spinal Fluid) would be calculated from images acquired with a TR = 6s. Then, the RF coil sensitivity map is obtained to correct the inhomogenity of the image coil. Finally, according to Eq.2 , with the corrected CASL data and calculated CSF data, which is represented as ⊿S_{CASL} and S_0csf, the dual coil CASL based cerebral brain flow(CBF) map is obtained, where parameters T_1, pld and pcasl are 1.33s ,700ms and 2s, respectively.

$$CBF = \frac{\Delta S_{CASL}}{0.93 \cdot S_{0CSF}} \cdot \frac{1}{2 \cdot T_1 \cdot (e^{-pld/T_1} - e^{-(pld+pcasl)/T_1})} \qquad (2)$$

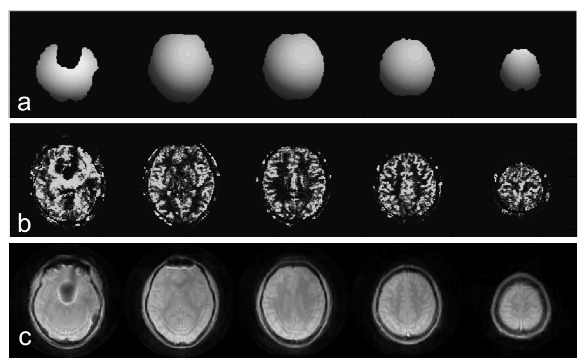

Figure 3 (a). RF coil sensitivity map; (b). CASL raw data; (c). Images for CSF calculation;

Results: The quantitative brain perfusion study was approved by the Ethics Committee of Hospital. One health subject (male, 29 years old) was studied at resting state. Fig.3 shows the obtained RF coil sensitivity map, CASL raw data and CSF image. In Fig 4, average gray matter of the CBF is calculated as 57.3±8.5mg/100ml/min for difference slices, which is consistence with previously reported physiological range (80 ml/100 g/min [4] and 48 – 62 ml/100 g/min [5]). The actual RF power delivered to the labeling coil was 1.5 w according to the power meter recording. By measuring the unloaded and loaded Q factors of the labeling coil pair (68 and 35), the absorbed power by the tissue was 51.5% of the input power (0.77 W) without exceeding FDA limitations, which is acceptable according to the FDA guidelines. For gray matter, the ratio of the subtracted image to the control image（⊿S/$S_{CONTROL}$) is 0.91% reflecting similar SNR to other two-coil systems (0.8% [2] and 0.95%([6]).

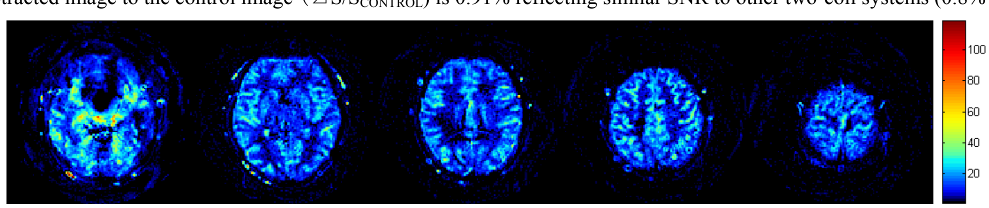

Figure 4 Calculated CBF map based on the DC-CASL

Conclusion: A portable RF transmitter for DC-CASL perfusion imaging is developed and demonstrated in this study. By using a dedicated labeling RF coil, the quantified brain perfusion results testified the feasibility of the proposed design. With its high quality imaging, minimized size and low cost, the separated coil based CASL setup may be valuable for further clinical usage and functional MRI study.

Reference : [1] Rolf P, et cl, MRM, 2010; [2] Zaharchuk G, et cl, MRM, 1999; [3] Talagala SL, et cl, MRM, 2004; [4] Mildner T, et cl, MRM, 2003; [5] Papadakis N, et cl, Magn Reson Eng B, 2006; [6] Qin X, et cl, Concept in Magn Reson Eng B, 2008.