Design of an Implanted RF Coil for Determining Input Function of Rat Carotid Artery at 9.4T

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ABSTRACT
An implanted vascular RF coil has been developed for determining input function of rat carotid artery at 9.4 Tesla. An in vivo spectral SNR of ~20:1 can be achieved in ~10 seconds when using this implanted coil to detect in vivo ^{17}O MR signal of natural abundance water from a small amount of blood of ~7.9 µl in rat carotid artery. RF shielding associated with the coil efficiently isolates the interest section of the vessel from surrounding tissues and ensures the signal detected by the coil only coming from the interest artery blood without other contaminations.

INTRODUCTION
Artery input function is an important factor in blood flow and oxygen utilization measurements using the tracer techniques in experimental animals. Many technical challenges make determining artery input function difficult. Some methods, which detect the MR signal from an external blood chamber outside animal body, have been reported (1-4). In this work, we developed a shielded vascular RF coil, which can be implanted into rat body and wrapped around the carotid artery for a more reliable measurement of artery input function by a direct detection of the ^{17}O MR signal.

MATERIALS and METHODS
The coil consisted of a modified solenoid, an RF shielding and a flexible cylindrical cradle former made from multi-layer parafilm as shown in Fig. 1. The modified solenoid had four turns and was constructed using lacquer coated copper wire with a diameter of 0.24mm. The whole coil was formed in a cylindrical shape and embedded in the parafilm former. The coil and its twisted leads were covered by copper foil which was served as RF shielding. The distance between the copper foil shielding and coil wire was 0.5mm. Finally the whole coil was sealed by a thin Teflon tape to ensure a good insulation between the coil and the carotid artery and as well as the surrounding tissues. The completed coil had a dimension of 3mm O.D. by 11mm length that is considered as a comfortably small size for surgical operation of rat. Frequency tuning/impedance matching were conducted by two variable capacitors located in a balanced tuning/matching network. The reflection coefficient S11 measurement was used to determine the coil's Q factors for both unloaded and loaded cases. To validate the performance of the implanted coil, ^{17}O MR spectroscopy combined with proton MRI using another large size proton coil were conducted in water phantom and rat carotid artery, respectively. All MR experiments with this coil were performed on a 9.4T horizontal bore magnet (Magnex Scientific, UK) interfaced to the Varian INOVA console (Varian Associates, Palo Alto, California).

RESULTS and DISCUSSIONS
The implanted coil was tuned to 54.3 MHz for ^{17}O at 9.4T. The unloaded and loaded Q factors measured were 57 and 28, respectively. According the coil length and the inner diameter of the artery, the detectable blood volume was about 7.9 µl. Fig. 2 shows ^{17}O spectra of water (in a glass capillary and in a surrounding chamber, respectively) and in vivo blood in rat carotid artery under its natural abundance using the implanted coil. SNR of in vivo ^{17}O spectra is ~20:1 in the acquisition time of ~10 seconds. Due to the much thicker wall (~0.4mm) of the glass capillary than that of rat carotid artery, the SNR of the blood in vivo was even better than that of the phantom. Fig. 3 exhibits proton images acquired with a 400MHz proton coil in the transverse and sagittal orientations of the same rat with the coil implanted. The results indicate that the RF shielding is efficient and the coil does not block the blood flow inside the carotid artery as indicated in the flow sensitive image (Fig. 3a). Fig. 4 illustrates the input function of the carotid artery obtained using the implanted coil and the ^{17}O spectra in the rat brain acquired using a head surface coil. The two spectra were acquired simultaneously with dual RF transmit and receiver channel. Our results indicate that SNR of ^{17}O will decrease if the RF shielding is too close to the solenoid. Increasing the distance between the RF shielding and the solenoid can definitely gain SNR. But the increased coil size will become unacceptable for the rat surgical operation.

CONCLUSIONS
An implanted vessel coil with RF shielding has been successfully designed. The method of detection of ^{17}O MR signal using the implanted coil to determine input function of rat carotid artery is feasible and efficient. This implanted coil would be also useful for quantifying the tracer concentration in artery.

ACKNOWLEDGMENTS
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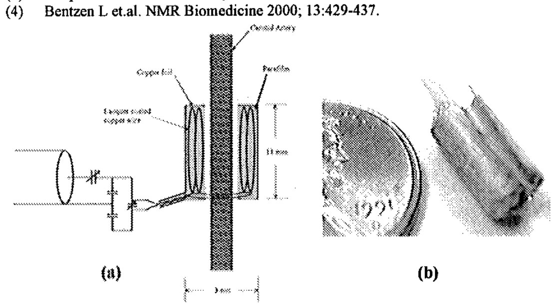

Fig. 1 A sketch (a) and a photograph (b) of the implanted vessel RF coil for measurement of input function of rat carotid artery.

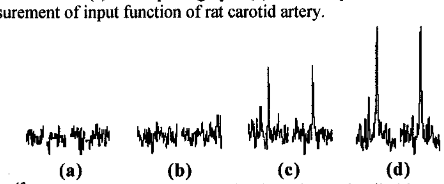

Fig. 2 ^{17}O spectra acquired using the implanted vessel coil: (a) empty coil, (b) coil wrapped by a chamber filled with natural abundance H_2O, (c) a glass capillary (o.d.=1.46mm, i.d.=0.66mm) filled with natural abundance H_2O, and (d) in vivo blood in the rat carotid artery of natural abundance.

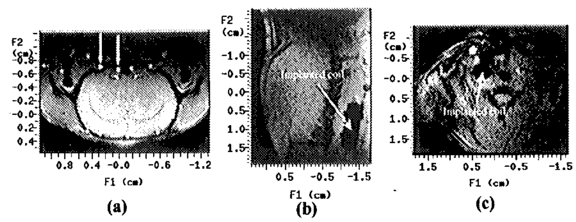

Fig. 3 GRE rat images acquired to validate the implanted vessel coil: flow sensitive image (a) shows the implanted coil did not block the carotid artery flow. Sagittal (b) and transverse (c) images indicate efficiency of the RF shielding and also the position of the coil.

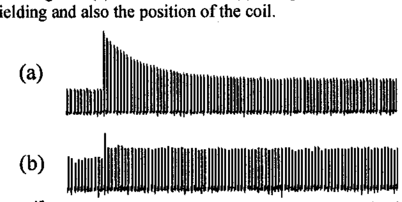

Fig. 4 ^{17}O spectra collected before, during and after bolus injection of 0.05cc $H_2{}^{17}O$ (40% atom) into rat internal carotid arterial from: (a) brain water using a surface coil on rat brain (from a 35µl voxel, T_{acq}=10.8 sec) and (b) artery water using the implanted vessel coil (nt=948, T_{acq}=10.8 sec).