Mouse Lumbar Spinal Cord Blood Flow (SCBF) Measurements by Arterial Spin Labeling

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Introduction:

A recent work has demonstrated the feasibility of mouse SC blood flow (SCBF) measurement with arterial spin labeling (ASL) using a presaturated flow-sensitive alternating inversion recovery (presat-FAIR) technique at the cervical level [1]. Accurate measurements of SCBF within structures of the cord were obtained.

The present study demonstrates that despite the SC motion at lower level, quantitative lumbar SCBF measurements can be achieved with ASL. This technique could permit efficient quantitative characterization of SC lesions and tissue blood supply deficiency, as well as longitudinal follow-up of diseases.

Methods:

Experiments were performed in mice (C57Bl/6J, age 14 weeks, 25 g. Anaesthesia: air+isoflurane (~1.4%), N=3 subjects) on a 11.75T vertical MR system (Bruker, AV 500WB) with a small transmitter/receiver volumic coil (inner ∅ 2 cm, length 3cm), well suited to mouse SC imaging. Due to the small size of the coil, the mice were positioned so that either the lumbar or the cervical regions were submitted to the RF pulses. SCBF measurements were then carried out in axial slices placed alternatively at the L2-lumbar and C3-cervical levels. Due to more amplified bulk motion in the lumbar region, the image acquisition was synchronized to the respiratory frequency (80±5 bpm). Images were acquired with an optimized 4-shot SE-EPI sequence [2] (TE=10.6ms, matrix 128x128, slice thickness 0.75 mm, FOV=1.7x1.7cm^2 for C3 and FOV=2.1x2.1cm^2 for L2). The presat-FAIR experiment was performed with the following parameters: inversion time (TI) of 1.3s, recovery time (τ) of 3.5s. The presat-FAIR signal ($\Delta M=M^{label}-M^{control}$) was averaged over 20 minutes for both C3 and L2 experiments. Since the coil did not provide a complete coverage of the subject, there was, in the label scan of the presat-FAIR sequence, a coil inflow time (Δ) effect that was taken into account for the SCBF quantification [3]. In our conditions, a Δ value of 2.7±0.2 s was measured. The presat-FAIR signal was therefore simply related to blood flow by $\Delta M= 2M_0.\alpha_0.(SCBF/\lambda).[(e^{-TI.R1app} - e^{-TI.R1a}) / (R1^a - R1^{app})]$ (eq 1) where λ is the water blood/tissue partition coefficient (0.9 ml/g) and $R1^a$ the longitudinal relaxation rate of arterial blood ($1/R1^a = 1/2.1\ s^{-1}$). The M_0 (equilibrium magnetization), α_0 (inversion efficiency) and $R1^{app}$ (SC tissue apparent longitudinal relaxation rate) parameters were determined with a slice selective inversion recovery prescan. Absolute perfusion quantification was obtained by solving equation 1 and SCBF values were evaluated in the L2 and C3 SC gray matter (GM) structures (Ventral Horn (VH), Dorsal Horn (DH) and whole GM).

Results:

Figure 1 shows anatomic SC EPI images (C3 (1a) and L2 (1d) levels) along with the corresponding enlarged SCBF maps (1c and 1f). The red dashed line (1b and 1e) delineates the SC boundaries. High-perfused gray matter structures (VH and DH) and low-perfused white matter are clearly visible on the C3 and L2 SCBF maps. When comparing images 1c and 1f, L2 GM perfusion appears to be lower than C3 GM perfusion. This tendency is also confirmed by the SCBF values measured on the 3 subjects and reported in table 1. The mean SCBF values show that for each GM structure, perfusion at L2 level is lower (~17%) than perfusion at C3 level. ROI standard deviations lower than 25% were found for both SCBF values at the C3 and L2 levels.

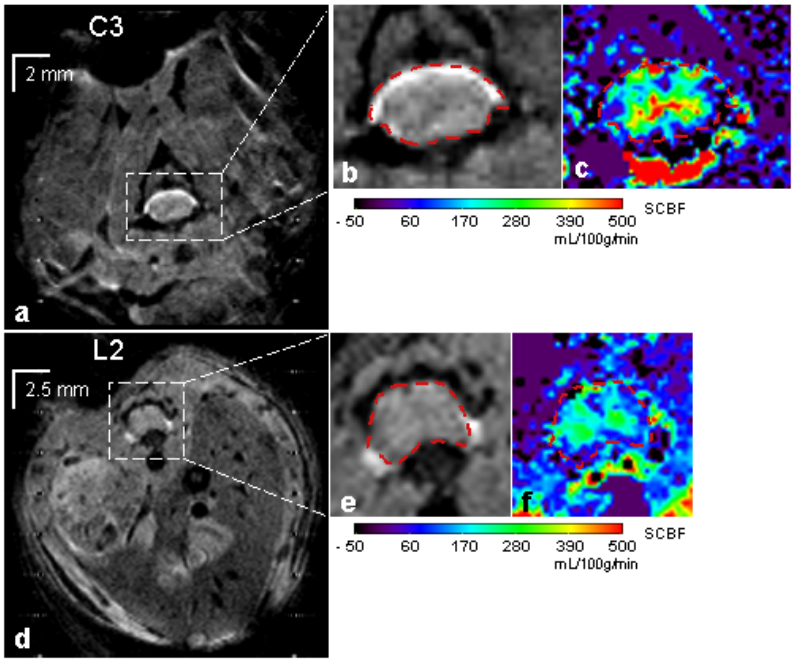

Fig 1: C3 and L2 SC EPI images (a, d). Enlarged C3 and L2 SC area (b,e) presented along with the corresponding quantitative SCBF maps (c,f). Resolution of 130x130 μm^2/pixel and 165x165 μm^2/pixel were achieved for the C3 and L2 SCBF maps respectively.

C3 level	*VH*	*DH*	*Whole GM*
Subject # 1	387±90	384±95	375±90
Subject # 2	327±84	311±66	320±100
Subject # 3	372±70	350±37	340±90
Group Mean + std	**362±31**	**348±37**	**346±27**
L2 level	***VH***	***DH***	***Whole GM***
Subject # 1	304±75	336±88	330±60
Subject # 2	257±30	214±58	224±43
Subject # 3	287±55	342±53	310±73
Group Mean + std	**283±24**	**297±72**	**288±56**
Difference in SCBF L2 vs C3	**-21 %**	**-14%**	**-16%**

Table 1 - SCBF values (mL/100g/min) measured at the C3 and L2 levels. Individual values are expressed as $mean_{ROI} \pm std_{ROI}$ and group values. as $mean_{group} \pm std_{group}$

Discussion:

The synchronization of image acquisition to the respiratory frequency greatly reduced the motion artefacts in the L2 level investigation (figure 1d). This study demonstrates that lumbar SCBF measurements can be performed by ASL in a similar way than cervical SCBF measurements [1]. According to the values reported in table 1, there is a tendency in the L2 GM SCBF values of being lower than the C3 GM SCBF values. These preliminary results, performed on 3 subjects only, need however to be confirmed and the spatial resolution need to be increased. One can note that perfusion measurements performed in rats with the hydrogen clearance method have already demonstrated differences in SCBF values with respect to the level of investigation (Cervical SCBF > Lumbar SCBF > Thoracic SCBF) [4]. This perfusion measurement method may be useful in the pathological description of rodent SC diseases in which deficient blood supply is involved (contusion, ischemia…) and where longitudinal follow-up is required.

References:*[1] Duhamel et al., MRM (2007) in revision, [2] Callot et al., Magn. Reson. Mater. Phy., MAGMA (2007) [3] Pell et al., MRM (1999), [4] Rubinstein et al., Neurosurgery (1990)*