Calibration of dynamic susceptibility contrast MRI using T1-based steady-state CBV (Bookend technique) and vascular space occupancy (VASO): Comparison with pseudo-continuous arterial spin labeling

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Introduction

Dynamic susceptibility contrast (DSC) MRI provides useful and reasonable maps of cerebral blood flow (CBF) in relative terms, although absolute values of CBF have commonly been overestimated, for example, due to partial volume effects [1]. Absolute values of perfusion are of importance in certain applications, and one approach to improve DSC-MRI in this respect is to quantify cerebral blood volume (CBV) with a complementary method, and to use this independent (and often ROI-based) CBV estimate for calibration of CBV and CBF from DSC-MRI. This has been done using the so-called Bookend technique, where T1 before and after contrast agent (CA) administration is recorded [2]. Another CBV method is the vascular space occupancy (VASO) approach, where an inversion recovery (IR) sequence, which nulls the blood before CA administration, is used before and after CA injection [3]. VASO CBV measurements can potentially also be used for calibration of DSC-MRI. Arterial spin labelling (ASL) is likely to return more reasonable absolute levels of CBF but does not provide other relevant parameters such as CBV and MTT [4]. The aim of this study was to calibrate DSC-MRI data using CBV obtained by Bookend and VASO, and to compare calibrated DSC-MRI estimates with CBF values from pseudo-continuous ASL (pCASL) [5].

Material and Methods

Twenty healthy volunteers (age 25-84) were scanned twice (test-retest) with 7-20 days between investigations on a 3T system. DSC-MRI data were collected using GRE-EPI with temporal resolution 1243 ms, echo time (TE) 29 ms and flip angle (FA) 60° after bolus injection of CA (0.1 mmol/kg b.w.). T1 was measured before and after CA administration using segmented 3D Look-Locker EPI (TFE factor 9, EPI factor 3, FA 5°), measuring 16 time points on the T1 relaxation curve with a time increment of 200 ms and a repetition time (TR) of 10 s. MRmap [6] was used for data fitting and T1 estimation. For VASO measurements, a non-slice-selective IR sequence (TR 6 s, TE 5.8 ms, TI 1088 ms, FA 90°) was employed. DSC-MRI, T1 measurements and VASO all used the same FOV of 220×220 mm^2 and matrix size 128×128. The DSC-MRI and VASO slice thicknesses were 5 mm (with slice gap 1 mm). Due to the need for comparable slices in the 3D Look-Locker acquisition, a slice thickness of 6 mm was employed. The pCASL sequence was executed using FOV 220×220 mm^2, matrix size 96×96, TR 4 s, TE 14 ms, label duration 1650 ms and 1600 ms post-label delay.

Segmentation of white matter (WM) was performed using SPM [7], and CBV in the resulting WM ROIs were estimated using the Bookend technique, VASO and DSC-MRI to obtain subject-specific calibration factors (CFs), according to $CF = CBV_{Bookend/VASO}/CBV_{DSC\text{-}MRI}$. The CFs were then applied to the whole DSC-MRI volume. Grey-matter (GM) CBF was extracted ($CBF_{Calibrated}=CBF_{DSC\text{-}MRI\ uncalibrated}\cdot CF$), and the calibrated DSC-MRI GM CBF values were compared with GM CBF from pCASL. Unfortunately, four pCASL scans showed non-optimized labelling, leading to unusable pCASL data, and data from these scans are not included in the results below.

Results

The mean GM CBF value in non-calibrated DSC-MRI was 278±65 ml/(min 100g) while the calibrated mean values were 40±13 ml/(min 100g) and 38±10 ml/(min 100g) using Bookend and VASO, respectively. The ASL mean value was 49±9 ml/(min 100g).

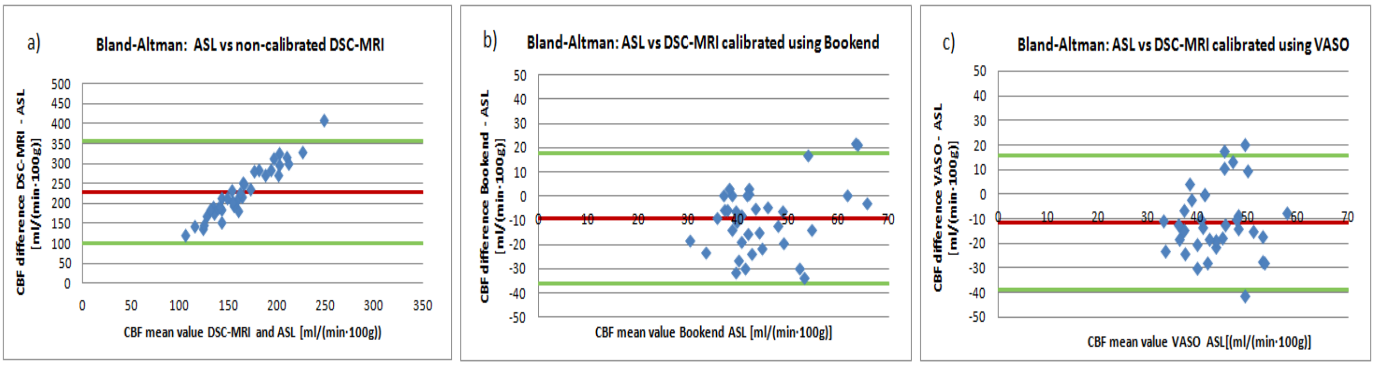

Figure 1. Bland-Altman plots comparing (a) non-calibrated DSC-MRI, (b) Bookend-calibrated DSC-MRI and (c) VASO-calibrated DSC-MRI with the corresponding pCASL CBF estimates for GM. The red lines show the mean differences between ASL and non-calibrated/calibrated DSC-MRI, and the green lines correspond to 1.96SD from the mean difference.

Discussion

The Bland-Altman plot comparing ASL with non-calibrated DSC-MRI indicates that DSC-MRI, as expected, overestimated the absolute values of CBF compared with pCASL. Bookend as well as VASO calibration tended to slightly underestimate CBF, but the difference compared with pCASL CBF was considerably smaller than for non-calibrated DSC-MRI. Both calibration approaches require comparison of two volumes, one acquired before and one after CA, which may be problematic, for example, in subjects with motion, and both methods also rely on quite small effects on the signal in WM because the CBV is only a few percent. However, both methods provided values comparable to pCASL and this study indicates that they have potential value as calibration methods for DSC-MRI.

References

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