Direct CBF comparison between MRI ASL and DSC and perfusion CT-scan in treated tumor patients

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Target audience: Neuroradiologists, Methodologists

PURPOSE The goals of this study were to assess the reproducibility of Dynamic Susceptibility Contrast (DSC) MRI and Perfusion-CT (PCT) and to compare the CBF estimates obtained with DSC, PCT, and Arterial Spin Labeling (ASL). We included patients with cerebral tumors, routinely monitored with these imaging methods. From a methodological point of view, tumors are challenging as they exhibit an altered blood-brain barrier and heterogeneous arrival times.

METHODS Eighteen patients with treated brain tumors (surgery in 10/18 patients, chemotherapy, and/or radiotherapy) of all grades and different OMS types underwent MRI and PCT on the same day with a mean delay of 2 hours. Cutaneous markers were used to co-localize MRI and PCT acquisitions. MRI was performed at 3T: T1-weighted structural image, ASL reference scan (M_0), pulsed ASL data (Q2TIPS[1], 4x4x5 mm voxels, 14 slices, 30 ctl/tag pairs, tag width: 200 mm, label gap: 15 mm, TI2/TI1: 1800/700 ms, TR/TE: 3000/24 ms, scan duration: 186 s) and 2 DSC sequences (EPI single-shot, 1.75x1.75x4 mm voxels, 40 dynamics, TR/TE/FA: 1634/40ms/75°, scan duration: 72 s; Gd-DOTA: 0.1 mmol/kg). The CT session included: 1 anatomical image and 2 PCT using iodine contrast agent (0.4x0.4x5 mm voxels, 30 dynamics, 8 slices, scan duration: 40 s; Iobitridol 300 mg: 40 mL). The two DSC and the two PCT scans were separated by ~20 min. MRI data were analyzed using SPM software and Matlab custom routines: (i) ASL images were realigned (frames exhibiting strong motion were excluded) and the difference between control and tag images was scaled to express CBF in ml/100g/min. (ii) DSC processing: an arterial input function (AIF) was obtained to deconvolve the signal of each voxel[2]. (iii) PCT processing was performed on a GE Healthcare clinical console with a deconvolution method using automatic AIF and venous output function selection[3]. PCT data were eventually coregistered to MRI data. A gray matter (GM) mask was obtained from the anatomical MRI (threshold level: 80%). The T_2-hyperintense region ("lesion", excluding resected area in case of surgery) was manually contoured. For each patient and each acquisition, the ratio between CBF in the lesion and in GM was calculated. The statistical significance was assessed using Pearson correlation coefficients (*:p<0.05, R>0.71, N=8).

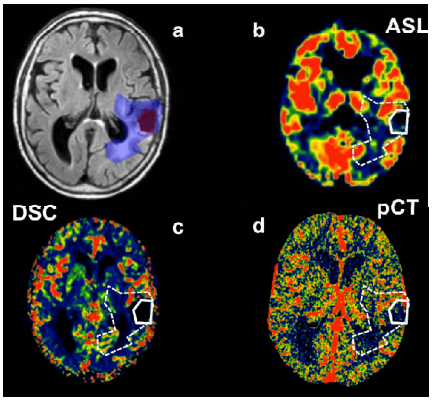

Figure 1: a) Manually defined ROI for one patient, in red the resected area and in blue the T_2-hyperintense lesion. b, c, d) ASL, DSC and pCT images for the same patient.

	DSC_1 vs DSC_2	CT_1 vs CT_2	DSC_1 vs ASL	CT_1 vs ASL	DSC_1 vs CT_1
Ratio Lesion/GM	0.99 *	1.00 *	0.58	0.81 *	0.83 *
Lesion	0.96 *	0.98 *	0.37	0.54	0.92 *
GM	0.78 *	0.77 *	0.17	0.37	0.72 *

Figure 2: Correlation coefficient to measure the reproducibilty of DSC and pCT and between each of the techniques (ASL, DSC, pCT)

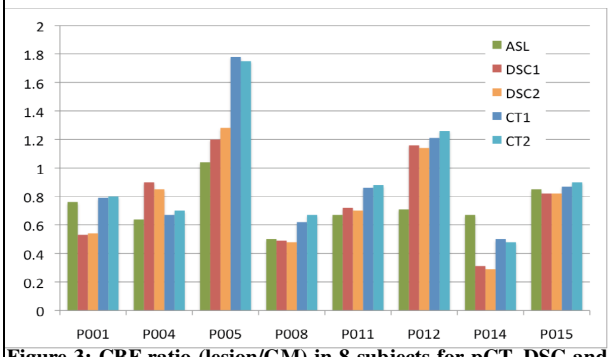

Figure 3: CBF ratio (lesion/GM) in 8 subjects for pCT, DSC and ASL methods

RESULTS Ten patients were excluded due to problems: 1) in pCT for 3 patients (low creatinine clearance, low coverage, inexploitable data), 2) in ASL for 2 patients (excessive motion), 3) in DSC for 4 patients (distorted DSC images, injection problems and motion), and 4) in acquisition management for 2 patients (missing data, protocol).

In the eight remaining patients, lesion/GM CBF ratios measured by PCT correlate significantly with CBF ratios measured by DSC and ASL (Figure 2). This is also true for absolute CBF measurements from PCT versus DSC in lesions and GM but not for PCT versus ASL. Correlation between DSC and ASL is not significant (Figure 2). The reproducibility of CBF data between injections for DSC and PCT acquisitions is excellent. There is no injection effect on the significance of the intermodality correlations (Figure 2).

There is a good agreement between each of the techniques in most subjects (Figure 3). Lesion/GM CBF ratios from PCT are higher than those from DSC measurements, excepted in patient 4. The difference is especially marked in patient 5 who is the only non-operated meningioma patient in the group. ASL seems to underestimate the perfusion in the lesion of the patient 12, as does DSC in patients 1 and 14.

DISCUSSION The comparison of perfusion data in the present group of patients is challenging due to the heterogeneity of the lesions. The good agreement between DSC and PCT likely arises from their methodological similarities (1^{st} pass approach, AIF deconvolution). The poor correlation of absolute CBF measurements obtained by ASL with the other modalities could be ascribed in part to a partial volume effect (larger voxels for ASL than for DSC and PCT) as well as weaknesses in our CBF quantification for DSC. The normalization reference for ASL quantification is based on GM segmentation which may need to be improved in the presence of tumors. The contribution of macrovessels appears also more important with first pass approaches. In DSC this may in part be addressed by using spin echo acquisition methods.

CONCLUSION Correlation between PCT, DSC and ASL measurements of CBF was assessed in a group of tumor patients. None of the methods provided CBF measures for all patients. The strong reproducibility of CT and DSC could elect these techniques for quantitative vasoreactivity challenges. A more detailed analysis of the present data could yield insights into the respective strengths and weaknesses of each method depending on the vascular properties.

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