Correlation between arterial blood volume obtained by arterial spin labelling and cerebral blood volume in intracranial tumours

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Abstract

Objective To compare measurements of the arterial blood volume (aBV), a perfusion parameter calculated from arterial spin labelling (ASL), and cerebral blood volume (CBV), calculated from dynamic susceptibility contrast (DSC) MRI. In the clinic, CBV is used for grading of intracranial tumours.

Materials and methods Estimates of aBV from the model-free ASL technique quantitative STAR labelling of arterial regions (QUASAR) experiment and of DSC-CBV were obtained at 3T in ten patients with eleven tumours (three grade III gliomas, four glioblastomas and four meningiomas, two in one patient). Parametric values of aBV and CBV were determined in the tumour as well as in normal grey matter (GM), and tumour-to-GM aBV and CBV ratios were calculated.

Results In a 4-pixel ROI representing maximal tumour values, the coefficient of determination $R^2$ was 0.61 for the comparison of ASL-based aBV tumour-to-GM ratios and DSC-MRI-based CBV tumour-to-GM ratios and 0.29 for the comparison of parametric values of ASL-aBV and DSC-CBV, under the assumption of proportionality. Both aBV and CBV showed a non-significant tendency to increase when going from grade III gliomas to glioblastomas to meningiomas.

Conclusion These results suggest that measurement of aBV is a potential tool for non-invasive assessment of blood volume in intracranial tumours.

Keywords Brain tumour · Blood volume · Arterial spin labelling · Dynamic susceptibility contrast MRI

Introduction

Gliomas are the most common primary tumours of the brain, with astrocytomas being the most common subtype. Astrocytoma grading is important for determining both prognosis and therapy. Vascular morphology is a critical parameter in assessing malignant potential and survival, since tumour growth beyond 1–2 mm largely depends on the development of adequate vascular supply [1]. Brain tumours disrupt the integrity of the blood brain barrier (BBB) and exhibit other pathological features, including marked angiogenesis with endothelial proliferation, severe hypoxia and tumour necrosis [2–4]. The degree of tumour angiogenesis and capillary permeability can be assessed by bolus-tracking perfusion MRI measurements, for example, dynamic susceptibility contrast magnetic resonance imaging.
Materials and methods

Materials

Ten subjects with intracranial tumours (three grade III gliomas, four glioblastomas and four meningiomas, two in one patient) were included in the study. In all patients, a contrast-enhancing lesion was present on post-contrast T1-weighted images. All gliomas were biopsy-proven. In the meningiomas, diagnosis was based on the typical imaging findings of an extra-axial homogenously enhancing mass lesion with dural extension. Four of the patients were men, and the median age of all patients was 49 years (range 35–68 years).

The study was approved by the local ethics committee, and written informed consent was obtained from all patients.

Image acquisition

MRI examinations were performed using a 3T scanner (Philips Achieva®, Philips Medical Systems, Best, The Netherlands) and included ASL (QUASAR) and DSC-MRI. ASL images were obtained with crushed arterial signal using a velocity-encoding gradient (crushed data) as well as with retained arterial signal (non-crushed data). Two flip angles were used to obtain equilibrium magnetisation in blood. QUASAR parameters were TR/TE/ΔTI/T11 = 4,000/23/300/40 ms, matrix = 64 × 64, seven slices (6 mm thickness/2 mm slice gap), FOV = 240 mm, flip angles = 35/11.7°, SENSE factor 2.5, Venc = [∞, 4 cm/s] and 82 averages (48 using Venc = 4 cm/s, 24 using Venc = ∞, 10 with smaller flip angle), implemented in a single pulse sequence. For DSC-MRI, gradient echo EPI was used with TR/TE = 1,360/29 ms, flip angle = 90°, 23 slices (5 mm thickness/1 mm gap), FOV = 220 mm, matrix = 128 × 128 and SENSE factor 2.5. A bolus (injection rate 5 ml/s) of 0.1 mmol/kg bodyweight gadolinium-based contrast agent (Dotarem®, Guerbet, Paris, France) was administered and followed by a saline flush.

Acquisition time was roughly 5 min for ASL and 1.5 min for DSC, in-plane spatial resolution was 3.75 mm² for ASL and 1.7 mm² for DSC, and spatial coverage was 56 mm (6 mm slice thickness and 2 mm gap) for ASL and 138 mm (5 mm slice thickness and 1 mm gap) for DSC-MRI.

Morphological data included transversal and sagittal T2-weighted sequences (TR/TE = 3,000 ms/80 ms), a FLAIR sequence (TR = 12000 ms/TE = 140 ms/TI = 2,500 ms), transversal pre- and post-contrast T1-weighted sequences (TR = 500 ms/TE = 10 ms) as well as a post-contrast coronal T1-weighted sequence.

Data processing

For ASL, all perfusion maps obtained using QUASAR were calculated offline using a computer program developed by one of the authors (E.T.P). A rejection algorithm was applied to exclude measurements influenced by excessive patient movement. By subtracting the crushed data from the non-crushed data, arterial signal curves were obtained. Arterial