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Comparison between dynamic susceptibility contrast magnetic resonance imaging and arterial spin labeling techniques in distinguishing malignant from benign brain tumors

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ABSTRACT

Objectives: The purpose of this study was to preliminarily compare unenhanced arterial spin-labeled (ASL) imaging, dynamic susceptibility contrast-enhanced cerebral blood volume (DSCE-CBV) magnetic resonance imaging (MRI) for evaluation of tumor perfusion in patients with brain tumors.
Materials and methods: A total of 27 patients with brain tumors were examined in 1,5 T MRI. Single phase and multiphase ASL, DSCE-CBV examinations were assessed by both qualitative and quantitative analysis for the detection of malignancy. Imaging results were correlated with a histopathology or follow-up.
Results: Based on 31 studies in 27 patients with brain tumors, the visual inspection sensitivities for ASL and dynamic DSC perfusion imaging were 88% and 94%, respectively, with 100% specificity for both. On qualitative evaluation, sensitivities for ASL and DSC perfusion imaging perfusions were 88% and 94%, respectively, with 100% specificity for both. The highest sensitivity values for quantitative ASL imaging were obtained using a normalized cut-off ratio of 1.65, resulting in sensitivity of 94% for ASL imaging and cut-off ratio of 1.95 and sensitivity 94% for DSCE-CBV imaging.
Conclusion: The present study revealed similar sensitivity and specificity for both multiphase ASL and DSC MRI. Thus, we suggest that ASL perfusion can be used in daily clinical practice.

1. Introduction

Brain tumors can be either primary or metastatic and generally has poor prognosis. Currently, contrast-enhanced magnetic resonance imaging (MRI) is the preferred method in evaluating brain tumors owing to its superiority in demonstrating anatomical details and facilitating detection of the sites where a blood-brain barrier has been impaired. However, it remains incapable in evaluating infiltration of malignant gliomas that do not show contrast substance uptake [1–3]. Intra cerebral lesion that uptakes contrast agent might not be tumor or every glial tumor that uptakes contrast agent might not be high-*grade*. Likewise, every glial tumor that does not uptake contrast agent might not be low-*grade*. Contrast agent uptake is basically associated with impaired blood-brain barrier [4]. Above-mentioned limitations of conventional MRI are tried to be overcome by advanced functional MRI techniques [5,6].

Perfusion MRI is a diagnostic method that visualizes a blood flow at a microscopic level and thus demonstrates even the angiogenesis that could not be detected on conventional MRI [7]. Blood flow at a microscopic level is visualized via perfusion analysis [8]. Perfusion MRI is valuable as it depict neovascularity of tumor tissue which is directly proportional to the tumor grade. DSC-CBVMRI is an accepted perfusion technique in routine practice among advanced MRI techniques that are used in the evaluation of intracranial tumors or tumor-like lesions and in grading glial tumors [9]. Arterial spin labeling (ASL) technique is a low-cost and non-invasive perfusion MRI technique that allows perfusion mapping as DSC perfusiondoes and requires nocontrast agenta dministration. Therefore, ASL perfusion technique is promising to be used in daily practice [10]. Several brain tumor studies have compared ASL with DSCE-MRI, focusing on perfusion ratios [11–15]. Typically, however, single-phase technique was used in

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these studies. There are only a few studies in current literature using multiphase ASL in the literature [16,17]. In this study, we utilized both single-phase and multi-phase ASL maps for the evalution of the increased perfusion.

The aim of the present study is to evaluate tumor perfusion in the patients, in whom both primary and secondary intracranial tumors has been detected on conventional MRI, and to compare ASL versus DSC perfusion imaging techniques to distinguish benign from malignant lesions.

2. Materials and methods

Records of all patients, in whom intracranial mass had been detected on imaging performed between 2011 and 2014 at Adnan Menderes University, Department of Radiology, were retrospectively reviewed. Patients had imaging results within at least six-month and utmost 2-year follow-up period. The diagnoses of the patients were performed either histopathologically or via follow-up MRI. Patients with unverified diagnosis and the patients having radiological images with an artifact that could influence the evaluation were excluded. A total of 27 patients that have been diagnosed with primary or metastatic brain tumor were enrolled in the study. Approval of the Ethics Committee of Adnan Menderes University was obtained for the study.

In this study, a total of 31 studies in 27 patients were evaluated. Post-operative follow-up images of 4 patients were also included in the study. Out of these patients, 13 were operated by neurosurgeons in our hospital including senior author (M.T.) in the current study. But not all of these patients had postoperative control MRIs. We use both pre-operative and post-operative images just for 4 patients.

Conventional brain MRI, DSC-MRI and ASL perfusion images of the patients were evaluated using picture archiving and communication system (PACS) and MR workstation. MRI was performed by 1.5 T MRI (Philips Achieva, Philips Medical Systems, Netherland B.V.). T1W axial, T2W axial, FLAIR axial, and T2W sagittal MRI sequences were obtained during conventional brain MRI. ASL perfusion sequence was obtained before administering MR contrast agent using an automatic injector. Afterwards, DSC sequence was obtained. Parameters of the conventional brain MRI sequence were matrix T1W 212×168, T2W 232×168, field of view = 210 mm, repetition time (TR) = T1W: 460 ms, T2W: 5700 ms, echo time (TE) = T1W: 10 ms, T2W: 110 ms, flip angle (FA) = T1W:69, T2W:90 thickness = 5 mm with 1-mm interslice gaps, number of slices = 23 and acquisition time of 90 s.

Parameters of the perfusion MRI sequence were matrix = ASL:68×68, DSC:88×88, field of view = ASL:240 mm, DSC:224 mm, repetition time (TR) = mpASL: 250 ms, spASL:4000 ms, DSC:1800 ms, echo time (TE) = mpASL:20 ms, spASL:25 ms, DSC:40 ms, flip angle (FA) = mpASL:35, spASL:70, DSC:75, thickness = ASL:6 mm, DSC:5 mm.

Pulse delay times for multi-phase ASL was 300 ms for each set of image, label thickness was 130 mm, and label gap was 20 mm. For single-phase ASL pulse delay time was 1200 ms, label thickness was 100 mm, and label gap was 20 mm.

Images of the patients, which have been obtained in accordance with our tumor protocol, were transferred to the workstation from PACS system for post-processing procedure. A total of 31 studies of 27 patients were evaluated. Existing software on the workstation was used to derive DSC and ASL perfusion maps. Prior to the evaluation of perfusion maps, conventional MRI sequences were evaluated to detect, localize and characterize the lesions. The lesion-observed on the conventional MRI sequences were found on DSC and ASL perfusion maps. DSC and ASL perfusion maps were qualitatively and quantitatively evaluated by two researchers (E.S.A. and C.E.).

2.1. Basic principles of single and multiphase ASL perfusion

The technique of generating pulsed single and multiphase ASL perfusion maps are described elsewhere [11–17]. Multi-phase ASL is especially important to visualize the temporal characteristics of the blood passage and the delineate the lesion in the best phase of acqusition. Several brain tumor studies have compared ASL with DSC-MRI, focusing on perfusion ratios [11–15]. However, there are only a few studies; using multiphase ASL in the literature [16,17]. Typically, ASL measurements are conducted at a single T1 between labeling and image acquisition in these studies. The effects of arterial arrival time or arterial transit time on CBF estimation is difficult to get the best enhancement of the signal and evaluation. This problem can cause misinterpretation and errors in interpreting the perfusion qualitative and quantitatively. Performing multiple ASL acquisition at various inversion times between labeling and image acquisition can be used to solve this transit time problem. In our multiphase technique, typically, as the parameter of the best illustration, the highest perfusion signal and the best tumor delineation are chosen among multiple acquisitions that are obtained 300 ms consequently. After the determination of the best multiphase image in an individual patient, the ASL image is interpreted qualitatively and quantitatively.

2.2. Evaluation of ASL perfusion

Perfusion maps were created for ASL perfusion on the workstation (Fig. 1). The lesions perfusion value measured from the highest signal intensity was normalized with the contralateral normal brain parenchyma for qualitative evaluation. Both single-phase and multi-phase ASL (48 imaging section) techniques were evaluated at the same session. The tumors were measured in the image that the most easily delineated.

In the multi-phase ASL mapping, each section was scanned at different time intervals of 300 ms consequently. Columns show different phases, whereas lines show different sections (Fig. 2). Maps were compared to each other to interpret the lesions perfusion and ipsilateral ROI is obtained from the highest perfusion signal. Among the ASL maps, for each study the sequence that the lesion was visible and shows the highest signal intensity was used for evaluation.

Qualitative evaluation was scored between 0 and 3 as 0 indicated hypointense as compared to brain parenchyma, 1 indicated isointense as compared to brain parenchyma, 2 indicated hyperintense as compared to brain parenchyma, and 3 indicated remarkably hyperintense. The lesions coded as 0 and 1 were considered benign, whereas the lesions coded as 2 and 3 were considered malignant.

For quantitative evaluation, relative regional CBF values were calculated. Therefore, in the comparisons analysis, relative regional CBF parameters that were obtained by ASL and DSC perfusion were used. In order to calculate relative regional CBF value, regions of interest (ROI) were drawn on the axial plane by free hand technique to make measures from localization of the lesion by detecting the lesion on the perfusion map. ROI was placed on the lesions by drawing as the largest area as possible according to the size and location of the lesion from the place that shows the highest perfusion. Cerebral arteries and veins were precisely examined on conventional MRI and on perfusion maps not to include these configurations in the measurement while measuring rCBF, and vascular configurations were excluded from measurement while measuring ROI.