3D PC Arterial Spin Labeling Outperforms Dynamic Susceptibility Contrast Techniques in the Surveillance of Primary Brain Neoplasms

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Authors: J. C. Rios¹, V. Velayudhan¹, Y. Parag², B. N. Delman¹, P. S. Pawha¹, G. Fatterpekar¹, T. Naidich¹, L. N. Tanenbaum¹; ¹New York, NY/US, ²Pittsburgh, PA/US
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Purpose

Dynamic susceptibility contrast-enhanced (DSC) first pass gadolinium-based perfusion techniques are used routinely in the surveillance of primary brain neoplasms and are of value in differentiating residual or recurrent tumor from treatment-related changes. Dynamic susceptibility contrast-enhanced techniques require the rapid bolus infusion of intravenous gadolinium, which may not be well tolerated by debilitated patients and can be contraindicated in patients with compromised renal function. Susceptibility artifact related to bony structures at the skull base, convexities and the orbits can significantly interfere with interpretation of EPI-based DSC techniques. Interpretation of DSC studies and quantification of perfusion parameters also can be confounded by blood-brain barrier breakdown and capillary leakage. Arterial spin labeling (ASL) can visualize and quantify cerebral perfusion via magnetic labeling of water protons in arterial blood without the need for an exogenous contrast agent and does not suffer from the same susceptibility related artifacts as DSC studies. The purpose of our study was to establish the practical equivalence or superiority of ASL-CBF to DSC and evaluate its performance against DSC in surveillance and characterization of brain neoplasms before and after treatment.
Methods and Materials

Materials

Dynamic Susceptibility Contrast (DSC) utilizes first pass tracking of a rapid bolus injection of a standard gadolinium-based contrast agent through the cerebral vasculature. The T2* susceptibility effects of gadolinium cause transient signal loss roughly proportional to the perfusion of tracer. Brain perfusion maps can then be generated from integration of data over the time course of the first pass of the contrast agent.[1-3 on page ]

Arterial Spin Labeling (ASL) is a technique that allows for quantitative brain perfusion imaging without contrast. This noncontrast technique is performed by magnetically labelling or spin labeling of water protons in blood flowing into the slices of interest. These labeled water molecules then exchange with the water in the tissues of interest, altering the magnetization in proportion to tissue perfusion. Subtracting this information from an unlabeled image can then allow for measurement of cerebral blood flow.[3-6 on page ]

Methods

A retrospective study was performed on 11 patients referred for MR imaging of primary brain neoplasms who underwent ASL and DSC perfusion imaging during the same session. Whole brain 3D fast spin-echo-based pseudo-continuous ASL perfusion studies were added to our established brain tumor imaging protocol, including routine pre and postcontrast imaging as well as DSC perfusion images. In some cases dynamic contrast-enhanced (DCE) permeability imaging was performed as well. All images obtained were evaluated with knowledge of the clinical circumstances and prior imaging was also compared when available. Images were evaluated by two experienced neuroradiology readers (LNT, BND) with respect to relative agreement and clinical contribution.

The reviewers retrospectively analyzed the 11 ASL and DSC perfusion examinations performed at the same sessions, comparing cerebral blood flow (CBF), and scored them via consensus in 4 categories: perfusion abnormality, lesion conspicuity, artifacts, and effects of leakage (if applicable).

Perfusion abnormality was compared to the perfusion of gray matter (GM) or white matter (WM). This was then rated from 1 to 5 utilizing the following scale: 1-Greater than GM, 2-Similar to GM, 3-Greater than WM, 4-Similar to WM, 5-Less than WM.
Conspicuity of the lesion was compared between DSC and ASL. The conspicuity was scored from 1 to 3: 1-ASL worse than DSC, 2-ASL equal to DSC, 3-ASL more conspicuous than DSC.

Artifacts were graded on a scale of 0 to 2: 0-No artifacts, 1-Artifacts that do not interfere with diagnosis, 2-Artifacts that do interfere with diagnosis.

Leakage affects were assessed for in cases where there was a discrepancy between DSC and ASL, in which case the DSC could be falsely positive due to leakage of contrast.
Results

The results are summarized in the following table.

<table>
<thead>
<tr>
<th>Patients</th>
<th>Perfusion Abnormality</th>
<th>Artifacts</th>
<th>Conspicuity</th>
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Table 1 - Results. Perfusion abnormality (1-Greater to GM, 2-Similar than GM, 3-Greater to WM, 4:-Similar than WM, 5-Less than WM). Artifacts (0-No artifacts, 1-Artifacts that do not interfere with diagnosis, 2-Artifacts that do interfere with diagnosis). Conspicuity (1-ASL worse than DSC, 2-ASL equal to DSC, 3-ASL more conspicuous than DSC).

Lesions were found to have similar appearing perfusion abnormalities with ASL compared to DSC studies in 4 of 11 cases (approximately 36%). Lesions were found to have greater signal on the ASL perfusion sequence compared to DSC in 6 of 11 cases (approximately 55%). Thus, the signal abnormality on ASL was equivalent or greater in approximately 91% of cases (Figures 1 and 2). In only one case was a lesion found to display greater perfusion abnormality on DSC than the ASL, possibly secondary to a leakage effect.

Similarly, lesions were found to have similar or greater conspicuity when comparing ASL to DSC in approximately 90% of cases (similar in 27% of cases and greater conspicuity for ASL in approximately 73% of cases). In only one cases was the lesion less conspicuous on ASL compared with DSC, possibly secondary to an artifact related to borderzone signal loss on ASL.
Artifacts were seen in all DSC cases compared to 4 of 11 (36%) ASL cases. Artifacts on DSC mainly related to susceptibility artifact near bony prominences (Figure 3) and vascular blooming (Figure 4) interfering with evaluation of lesions. For ASL, the most important artifact was borderzone signal loss, most prominently in the MCA/PCA borderzone posteriorly (Figure 5). Of the DSC cases, artifact was found to interfere with diagnosis in approximately 55% of cases (Figure 6). In only one cases did the borderzone signal loss on ASL interfere with interpretation, the only case in which the lesion was more conspicuous on DSC than on ASL. In order to eliminate or minimize the regions of borderzone dropouts, adjustments can be made to the imaging delays after the labeling of water protons.
Fig. 0: Lesion Conspicuity: This patient underwent subtotal resection of a low grade astrocytoma situated near the left vertex. The postoperative contrast enhanced T1WI do not demonstrate avid enhancement (A). The extent of the lesion is better appreciate on FLAIR images with signal alteration around the margins of the resection (B). The DSC images demonstrate no more than modestly elevated CBF (C) and CBV (D). However, the ASL CBF (E) demonstrates far more striking increased blood flow to the area with T2 prolongation that is suggestive of residual viable tumor. The greater conspicuity is at least in part related to the greater dynamic range of ASL when compared to DSC perfusion MRI. Thus, ASL can be especially useful in demonstrating the extent of nonenhancing or minimally enhancing tumors, such as this low grade glioma.

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Fig. 0: In this patient, the non-contrast head CT (A) demonstrates a coarsely calcified lesion in the right temporal lobe. The post-contrast T1-weighted (B) sequence shows mild enhancement. The T2-weighted sequence (C) reveals greater involvement than that shown on post-contrast imaging. On DSC perfusion imaging, CBF (D) and CBV (E) demonstrate moderately increased perfusion to the right temporal lobe and slightly increased perfusion extending into the adjacent subinsular and capsular regions. The ASL study (F), demonstrates more striking increased blood flow to the temporal lobe and adjacent subinsular and capsular region more in line with the involvement seen on the T2-weighted images giving the lesion overall greater conspicuity on the ASL images.

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Fig. 0: DSC Susceptibility Artifact: This patient is a 35 year old female undergoing surveillance of a sphenoid wing meningioma with components in the left sphenoid bone,
orbit and middle cranial fossa as seen on this post contrast T1 weighted image (A). On the DSC CBF (B, overlayed on postcontrast T1WI in image C), susceptibility artifact obscures the lesion within the sphenoid bone such that the tumor is not well seen at all. However, the ASL CBF (D) image demonstrates floridly increased perfusion to the tumor with no obscuration of the lesion.

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**Fig. 0:** DSC Vascular Blooming Artifact: This patient is a 52 year old female who underwent resection of a glioblastoma with oligodendroglioma and gliosarcoma components. A rind of tissue on FLAIR imaging (A) remained along the anterior margin of the resection cavity in the left middle cranial fossa abutting the lesser sphenoid wing.
Blooming artifact from the adjacent MCA makes the lesion less conspicuous on CBF (C) and CBV (D). Small areas of viable tumor with abnormally increased perfusion are more clearly seen here on the ASL image (B) along the anterior margins of the resection cavity.

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**Fig. 0:** ASL Borderzone Artifact: These three examples (A, B, C) demonstrate the appearance of borderzone signal dropout, which is usually more prominent posteriorly at the MCA-PCA vascular borderzone.

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Fig. 0: ASL Borderzone Artifact Obscuring Interpretation: In this case, the patient was an 85 year old female with a gliobastoma, which enhances avidly on the postcontrast T1 weighted image (A). The lesion is seen on ASL (B), but may have been even more conspicuous if it did not lie directly within the area of borderzone signal dropout. This artifact does not occur on DSC perfusion images, CBF (C) and CBV (D).

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Conclusion

We conclude that, in our patient population, ASL CBF can demonstrate tumors with similar or better conspicuity as compared to DSC. ASL lacks artifacts related to vascular blooming or susceptibility and may be better at assessing lesions near bony prominences, such as in the middle cranial fossa, orbits, skull base or intraosseous lesions. Further, ASL is resistant to leakage effects as it is a noncontrast technique. It may also be useful in the evaluation of nonenhancing lesions, similar to DSC. ASL should be considered in patients who are unable to tolerate IV contrast or in those with renal compromise for which gadolinium is contraindicated.
References


Personal Information

J. C. Rios, V. Velayudhan, Y. Parag, B. N. Delman, P. S. Pawha, G. Fatterpekar, T. Naidich, L. N. Tanenbaum. Department of Radiology, Mount Sinai School of Medicine, 1 Gustave L. Levy Place, Box 1234, New York, NY 10029. Email to: nuromri@gmail.com