

## A Novel MRI Technique for Assessing Collaterals in Acute Ischemic Stroke

Jeong Pyo Son<sup>1</sup>, Suk Jae Kim<sup>2</sup>, Sookyung Ryoo<sup>2</sup>, Mi-Ji Lee<sup>2</sup>, Jihoon Cha<sup>3</sup>, and Oh Young Bang<sup>1,2</sup>

<sup>1</sup>Department of Health Sciences and Technology, Samsung Advanced Institute for Health Sciences and Technology, Sungkyunkwan University, Seoul, Korea,

<sup>2</sup>Department of Neurology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea, <sup>3</sup>Department of Radiology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

**Introduction:** Rapid assessment of collateral status is critical for refining therapeutic decision-making in patients with acute ischemic stroke.<sup>1</sup> To date, digital subtraction angiography (DSA) is considered to be the gold standard for evaluation of collateral flow in stroke patients who are candidates for endovascular treatment. However, DSA is invasive, relatively time consuming to perform, require expertise, and has a risk of thrombotic complications. Recently, there have been growing efforts to visualize collaterals using noninvasive imaging methods, including dynamic susceptibility contrast-enhanced perfusion-weighted imaging (DSC-PWI). In this study, we applied a novel MRI technique employing DSC-PWI source data to visualize leptomeningeal collateral circulation in acute ischemic stroke with a major artery occlusion. A collateral grading system based on this new MRI method was also developed by comparing it with conventional DSA.

**Methods:** Consecutive patients who were eligible for recanalization therapy underwent MRI and DSA for acute middle cerebral artery (MCA) infarction at a university medical center. MRI was performed using a Philips Achieva MR scanner (Philips Medical Systems, Best, Netherlands) operating at 3 Tesla. The DSC-PWI was performed using gradient-echo and echo-planar imaging techniques after administration of intravenous gadolinium (Dotarem (Gadoterate Meglumine), Guerbet, Aulnay-sous-Bois, France) with a repetition time of 1718 milliseconds for a total acquisition time of approximately 90 seconds with 20 slices with temporal resolution of 1.8 seconds. A total of 1000 DSC-PWI raw images composed of 50 time series per slice was obtained. A collateral flow map derived from PWI source data was generated by semi-automatic post-processing using in-house MATLAB (Math Works Inc., Natick, MA, USA) scripts. The images were made by subtracting each cut from the first one to eliminate signal intensity from anatomical structures and visualize only the effect of gadolinium filling. Then the images were merged across two as they provided better temporal and spatial resolution. To generate the collateral flow map, DSA and images of two merged cuts from DSC-PWI were matched (Figure 1). DSA consists of arterial, capillary, and venous phases. Based on the intensity of contrast staining and washout of the lesional and contralesional hemispheres, DSC-PWI images of two merged cuts corresponding to each phase of DSA were selected. Finally, to obtain better spatial resolution for the evaluation of collaterals, images of each arterial, capillary, or venous-late venous phase were summated as early, mid, or late phase, respectively. Figure 2 demonstrates typical examples of collateral grading as determined by the collateral flow map and DSA. The criteria for collateral flow-map-based collateral grade were chosen based on the concept of the ASITN/SIR scale.<sup>2</sup> All the statistical analyses were done by calculating weighted  $\kappa$ -coefficients ( $\kappa_w$ ) to quantify the level of agreement regarding the grade of collaterals to determine intra-/inter-observer and inter-modality variability.

**Results:** Of 68 patients, 42 (61.8 %) had M1 occlusion and 26 (38.2 %) had ICA occlusion. The time interval between MRI scanning and the start of DSA was  $80.8 \pm 48.6$  minutes. Both the collateral flow map and DSA showed good inter-observer agreement of collateral grade ( $\kappa_w = 0.817$  for collateral flow map and 0.757 for DSA). There was good correlation between MRI- and DSA-based collateral grades: 68 % had the same grade in the same patient (Figure 3,  $\kappa_w = 0.653$ ). In most patients who had mismatches between the two modalities, the collateral grade was higher in MRI-based vs. DSA-based assessment.

**Discussion and Conclusion:** Our study demonstrated that a collateral flow map can be easily created with semi-automatic post-processing. This map can provide information about collateral circulation with excellent intra- and inter-observer agreement (all  $\kappa_w > 0.8$ ). Compared with DSA, the accuracy of the collateral flow map was good, and most of the patients who had mismatches between the two modalities had a higher collateral grade with the collateral flow map than with DSA. This may be explained by the fact that the visualization of collateral flow in the collateral flow map was better in some patients who showed poor visualization of collaterals in DSA. There are several strengths of collateral flow mapping. As the collateral flow map is generated using DSC-PWI source data, additional scan time is not needed. Post-processing is simple and can be easily done by semi-automatically. Co-registration with other MR images such as DWI and PWI is also possible. Therefore, this modality might provide more comprehensive knowledge about the status of collaterals in patients in the setting of acute stroke. In conclusion, this study suggests that collateral flow map generation using DSC-PWI source data is possible and reliable. As pretreatment collateral flow is a key factor in determining tissue fate, further studies examining the role of collateral flow maps in therapeutic decision making in patients with acute ischemic stroke are warranted. Given that we used routine PWI source images in this study, the application of our method in a rapid prospective fashion may be feasible in acute clinical settings.

**References:** (1) Bang OY, Saver JL, Kim SJ, et al. Collateral flow predicts response to endovascular therapy for acute ischemic stroke. *Stroke* 2011;42:693-699. (2) Higashida RT, Furlan AJ, Roberts H, et al. Trial design and reporting standards for intra-arterial cerebral thrombolysis for acute ischemic stroke. *Stroke* 2003;34:e109-137.

