Three-Dimentional Stereotactic Surface Projections Applied to Arterial Spin Labeling in a Clinical Population

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Target audience: Neuroradiologists, neurologists, engineers and physicists.

Introduction: Arterial spin labeling (ASL) provides a robust, quantitative method of evaluating cerebral blood flow (CBF) that adds clinical value in the diagnostic evaluation of a wide range of pathologies including acute ischemic stroke, brain tumors, infection, demyelinating disease and dementia[1]. While ASL can assess an individual's cerebrovascular status, visual inspection and/or region-of-interest analyses are often challenging to interpret, and a statistical brain mapping technique using a reference normative database from a disease-free control population is of potential benefit in the evaluation of intrasubject CBF changes. We investigated the diagnostic applicability and performance of three-dimensional stereotactic surface projections (3D-SSP)[2], a commonly used tool for molecular brain PET imaging, as applied to ASL in clinical MR examinations.

Methods: A retrospective sample of 10 consecutive patients who underwent ASL as part of a clinically indicated MR examination on a 3T system (Ingenia, Philips Healthcare, Best, The Netherlands) was collected during this pilot study. Five additional subjects with normal cerebral perfusion served as a control group. All images were acquired with a pseudocontinuous ASL preparation (Labeling Duration = 1.8 s, Post Label Delay = 2.0 s.) and the following imaging parameters: 20 slices; FOV=230x230x120 mm^3, resolution = 3.6x3.6x5 mm^3, EPI factor = 31, SENSE reduction factor = 2.3, TE=7.8, and background suppression pulses at 1830 and 3370 ms. Voxelwise cerebral blood flow (CBF) quantification was calculated, per subject, from parameter-matched, M0 maps using in-house MATLAB (The Mathworks, Natick MA) scripts based on[1]. Stereotactic anatomic standardization was performed by methods described previously[2]. 3D-SSP extracted maps were then generated for the control group, and subsequently for subjects, from individual data sets consisting of the following steps: (a) anatomic standardization to the Talairach atlas[3] of an individual's ASL image set by stereotactic transformation, (b) data extraction for cortical CBF to a set of predefined pixels (3D-SSP), and (c) with and without data normalization to the thalamic activity. A normal database was created from averaging the extracted CBF datasets of the control group. Subject 3D-SSP Z-score maps were then generated relative to the control group based on the following steps: (d) calculation of the Z-score on a pixel-by-pixel basis for an individual's dataset compared with the normal group (decreased CBF relative to normative mean CBF/standard deviation of normative CBF), and (e) data presentation in three dimensions, generating the 3D-SSP views, as illustrated in Figure 1. Two fellowship-trained neuroradiologists that were blinded to technique and all clinical information then evaluated the M0-corrected CBF maps and 3D-SSP maps, presented in random order, using the following metrics and a 3-point scale: 1) Image quality; 2) Ease of identifying abnormalities; 3) Location of identified abnormalities; 4) Confidence in having not missed additional relevant findings; and 5) Confidence in identifying the exact location of hypoperfusion.

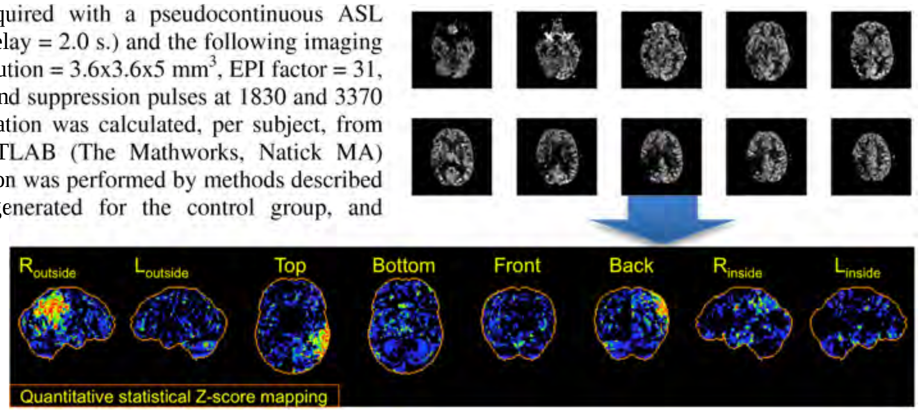

Figure 1: M0-corrected CBF data is converted to 3D-SSP data.

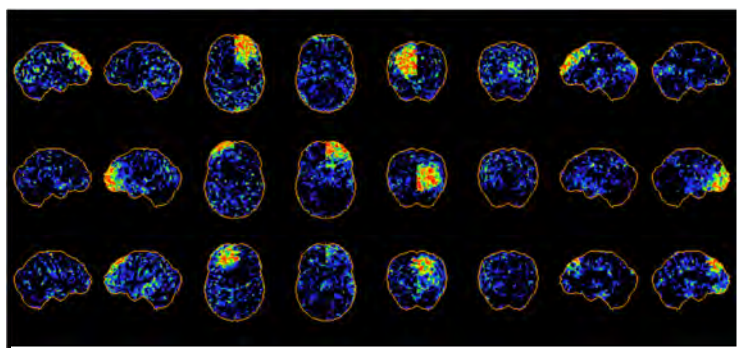

Figure 2: Three select individual cases illustrating 3D-SSP maps derived from M0-corrected ASL data.

Results: Patterns and severities of reduced CBF are identified in tumor resection cavities, follow-up stroke regions, and in patients with notable regional hypoperfuion, seen in the standard 3D-SSP maps (4 standard deviations, red color), three of which are depicted in Figure 2. Reader assessment demonstrated that image quality, ease of identifying abnormalities, and confidence in identifying the exact location of hypoperfusion were all significantly higher for the 3D-SSP maps ($p = 0.015$, 0.002, and 0.002, respectively, by paired, two-tailed t-test). Expert neuroradiologist reader assessment demonstrated that 3D-SSP images were preferred, in general, over the traditionally displayed CBF maps and that 3D-SSP maps were never found to be inferior to the M0-corrected CBF maps, across all assessed imaging metrics.

Discussion: 3D-SSP statistical mapping is feasible in a clinical population and enables quantitative data extraction and reliable localization of perfusion abnormalities by means of stereotactic coordinates in a condensed display. This method can be easily applied to a variety of clinical populations for improved diagnostic confidence.

Conclusions: The proposed 3D-SSP method is a promising approach for interpreting ASL MR-derived cerebrovascular pathology. Application of this technique to a broader clinical population will likely be of clinical benefit.

References: [1] Alsop DC, et al. MRM 2014 Apr 8. [2] Minoshima et al. J Nucl Med. 1995;36:1238-1248. [3] Talairach J and Tournoux P. Co-planar stereotatic atlas of the human brain. Stuttgart, New York: Thieme, 1988.