IVIM Perfusion Fraction in Acute Stroke: Initial Clinical Experience

Christian Federau[1], Suna Sumer[2], Fabio Becce[1], Kieran O'Brien[3], Reto Meuli[1], and Max Wintermark[2]

[1]Radiology, CHUV, Lausanne, Vaud, Switzerland, [2]Neuroradiology Division, Department of Radiology, University of Virginia, Charlottesville, Virginia, United States, [3]Center for Biomedical Imaging (CIBM), University of Geneva, Geneva, Switzerland

Purpose

Local brain perfusion measurement, either with MRI dynamic susceptibility contrast (DSC) or CT perfusion (CTP), is currently used clinically in the context of acute stroke to assess altered perfusion, while restriction in diffusion-weighted imaging is used to assess the ischemic core, and their mismatch the salvageable tissue, also called penumbra. Because both DSC and CTP depend on the arterial input function (AIF), both may fail to properly take into account leptomeningeal collateral blood flow supply, which is essential for clinical prognosis [1]. Measuring perfusion with Intravoxel Incoherent Motion (IVIM) MRI [2] might theoretically solve this issue, as it is independent on the AIF, and thought to be mainly dependent on the local microvascular perfusion. It would also allow a gain of time, as no i.v. contrast medium is needed, and therefore, no vein puncture before imaging is necessary. To our knowledge, only one study of IVIM perfusion fraction measurement in acute ischemic stroke in human patients has been reported [3], without maps, and with somewhat counterintuitive quantitative results, the majority of f values being reported as negative in the infarcted area. In the context of a regain of interest in IVIM as a method to measure brain perfusion [4-6], we re-evaluated IVIM perfusion measurement in the context of acute stroke.

Methods

Images were collected in patients who presented with symptoms of acute ischemic stroke. Exclusion criteria were onset of symptoms to imaging > 5 days, hemorrhagic transformation, infratentorial lesions, and small lesions < 1 cm in minimal diameter. We collected 17 cases (Fig. 1). IVIM images were performed at 3 Tesla, using a spin-echo sequence with embedded Stejskal-Tanner pulsed gradients, with parameters as previously described [4], using 16 b-values from 0 to 900 s/mm^2 in 3 orthogonal directions. Quantitative analysis was performed by placing a ROI around the largest stroke area on an axial slice, as defined by reduced ADC, and in the collateral region, avoiding cerebro-spinal fluid. The trace of the signal was first averaged for each b value, before fitting the bi-exponential IVIM model [2].

Results

Parametric IVIM perfusion maps showed an area of decreased perfusion fraction f, not always fully overlapping with the region of decreased ADC (Fig. 2). Quantitative analysis showed high statistically significant decrease in both IVIM perfusion fraction f (0.026 ± 0.019 vs 0.056 ± 0.027; p = 9.5 · 10^{-5}) and diffusion coefficient D in comparison to the contralateral side (3.9 ± 0.85 · 10^{-4} vs 7.7 ± 0.98 · 10^{-4} mm^2/s; p = 1.4 · 10^{-10}) (Fig. 3).

Discussion

IVIM perfusion fraction is significantly reduced in the visible infarct in acute ischemic stroke. Further studies should evaluate the potential for IVIM in predicting clinical outcome and treatment response.

References

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Age	56.2 ± 23.4
Sex	12 males, 5 females
NIHSS at entry	7.7 ± 5.4
Onset to imaging	45.5 ± 40.3
Treated with tPA i.v.	6

Fig 1: Patient demographics: age (years), sex, NIHSS clinical severity score, onset of symptoms to IVIM imaging (hours), and number of patients treated with i.v. tPA before imaging. Avg ± std dev, when appropriate.
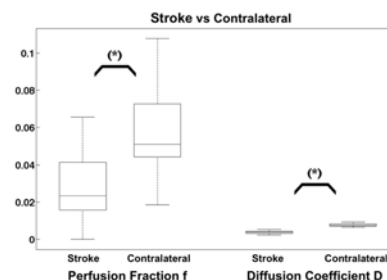

Fig 3: Quantitative analysis, showing a statistically significant decrease in IVIM perfusion fraction and diffusion coefficient in the stroke area in comparison to the contralateral side. [f] = scalar, [D] = 10^{-2} mm^2/s
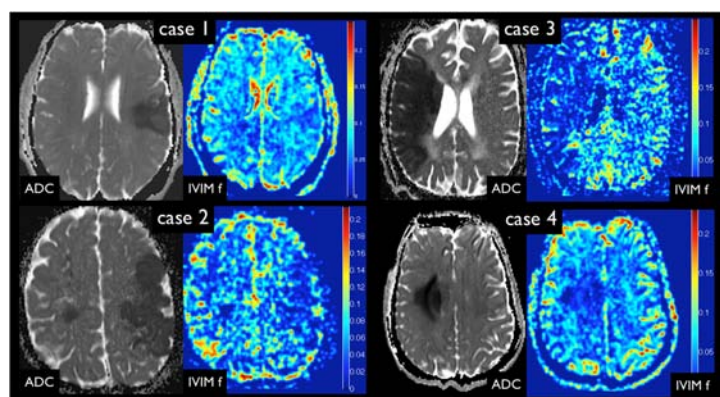

Fig 2: 4 cases of acute stroke showing the decreased IVIM perfusion fraction in the regions of reduced ADC. Note that regions of decreased ADC and decreased f do not always fully overlap, for example in case 4, the hypo-perfused area is larger and reaches the midline.