Improved Venous Output Function using MR Signal Phase for Quantitative 2D DCE-MRI in Human Brain

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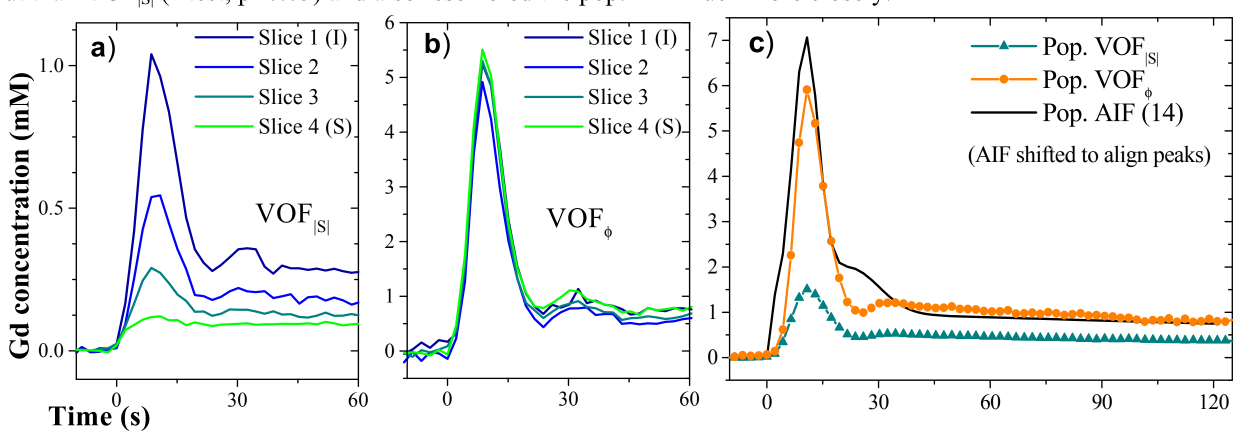
Introduction: Quantitative dynamic contrast-enhanced (DCE) MRI in the human brain provides valuable diagnostic information (1). For quantitative DCE-MRI, the contrast agent concentration-vs-time ([C](t)) in the superior sagittal sinus (SSS) gives the venous output function (VOF). The VOF can be used to correct partial volume artifacts in the arterial input function (AIF), which is crucial for accurate estimation of perfusion parameters (2,3). Unfortunately, measuring the VOF with MR signal magnitude (|S|) can be difficult due to inflow, especially for multislice (2D) sequences, and saturation of |S| at high [C] (4-6). Some researchers have been investigating the use of MR signal phase (ϕ) for measuring the VOF and/or AIF for quantitative DCE-MRI (5-8). ϕ is linear and non-saturating with [C] (9-11); it is relatively insensitive to blood flow (12), partial volume effects (5), and flip angle variations (5-13); and it typically has a greater SNR than |S| (13). It is therefore hypothesized that ϕ will provide more accurate and precise VOFs compared to |S|. The purpose of this study was to assess the accuracy and precision of |S|-derived VOF measurements ($VOF_{|S|}$) compared to ϕ-derived VOF measurements (VOF_{ϕ}) for multislice (2D) DCE-MRI studies of the brain (n=28).

Methods: Raw data were saved from twenty-eight 2D DCE-MRI studies performed during routine, clinical, Gd-enhanced brain exams (1.5T Siemens Symphony). A spoiled gradient echo sequence was used with the following parameters: TR=45 ms, double TE = 2.06 and 5.48 ms, flip = 90°, four 5.5 mm-thick transverse slices (2.75 mm gap), temporal resolution = 2.2 s, Gd dose = 0.07-0.1 mmol/kg. An ROI was drawn inside the SSS of each slice, providing |S|(t) and ϕ(t). $VOF_{|S|}$ was computed from |S|(t) using standard signal equations, extrapolating to TE = 0 ms and assuming $T_{1,0}$=1250 ms (5-8,14). VOF_{ϕ} was computed from ϕ(t) (TE=5.48 ms), accounting for the angle of the segment of SSS with respect to the main magnetic field (5-13). The peak amplitude, area-under-the-curve up to 30 seconds (AUC_{30}), and washout amplitude (mean from 80 to 100 seconds) were computed for each VOF.

Results and Discussion: Figs 1a and 1b show, for one study, whole-blood $VOF_{|S|}$ and VOF_{ϕ} as a function of slice (inferior-superior). The peak amplitude of $VOF_{|S|}$ varied significantly as a function of slice location (1-way ANOVA, p=<0.001) whereas that of VOF_{ϕ} did not (p=0.9). This likely reflects the insensitivity of ϕ to inflow and partial volumes, compared to |S|. Therefore, only the slice with max $VOF_{|S|}$ was used for the final $VOF_{|S|}$ calculation, whereas the average of all slices was used for the final VOF_{ϕ} calculation. Fig 1c and Table 1 show average and study-to-study variation of $VOF_{|S|}$ and VOF_{ϕ} as well as comparison with a recently published population-based AIF (14), which should have characteristics similar to a VOF. VOF_{ϕ} had a smaller coefficient of variation in peak, AUC_{30}, and washout than $VOF_{|S|}$ (f-test, p<0.03) and also resembled the pop. AIF much more closely.

Fig 1 a) $VOF_{|S|}$ and b) VOF_{ϕ} for one study, showing slice dependence. c) VOFs averaged over all 28 studies, compared to published pop. AIF.



Conclusion: For 2D DCE-MRI in human brain, phase-derived VOFs are more precise and more accurate than magnitude-derived VOFs.

Table 1	Peak (mM)	AUC_{30} (mM s)	Washout (mM)
$VOF_{\|S\|}$	1.5 ± 0.9	300 ± 180	0.4 ± 0.2
VOF_{ϕ}	6 ± 2	900 ± 300	0.9 ± 0.3
Pop. AIF (14)	7.1	800	1.0

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Acknowledgments: Kiwanis Club of Ottawa Medical Foundation, Dr. Kanta Marwah, Brain Tumour Foundation of Canada