Automated Computation of the Arterial Input Function for Dynamic Susceptibility Bolus Tracking Brain Perfusion MRI

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INTRODUCTION:

To fully automate the computation of perfusion metrics from dynamic susceptibility contrast (DSC) bolus tracking data, we revisited the automatic selection of the arterial input function (AIF). We noted that standard deviation (SD) maps of DSC data reliably emphasize vasculature over other tissue classes, and hypothesized that such maps could be used to select the AIF. To facilitate rapid processing in a clinical setting, we approached the task by applying successive filters based on SD to rapidly reduce the number of candidate voxels, rather than calculating metrics for each voxel in the image. This results in a reliable AIF produced by a small population of "best candidate voxels" rather than a "single best voxel."

MATERIALS and METHODS:

Subjects: Thirty-five consecutive DSC T2* perfusion studies from patients with brain tumors scanned under IRB approved protocols.

Data Acquisition: DSC T2* perfusion data (Table 1) was obtained during the bolus injection of 0.1 mmol / kg Gd based contrast (Magnevist or Prohance) at 2-4 cc/sec through (at minimum) a 21 ga. peripheral line. In all cases, this was a *second* injection of contrast, as a single dose (0.1 mmol/kg) was injected approximately 15-20 min earlier for dynamic contrast enhanced (T1 weighted) imaging. This eliminated or minimized the confounding effects of first pass rapid contrast leakage on DSC in tumors.

Table 1.	Field	Scanner	Mode	Sequence	TR	TE	FA	FOV	AcMAT	RecMAT	Slices	Thick	Nvol
T2* DSC bolus tracking parameters	1.5T	GE Signa	2D	Single Shot GE EPI	1500	51	90	220 mm	96x96	128x128	12-14	5 mm	42
	3.0T	Philips Intera	2D	Single Shot GE EPI	1500	18	40	220 mm	128x95	256x256	28	5 mm	36

Analysis: Data was transferred as DICOM to Linux workstations using Kodak PACSweb. The MEDx scripting language (Medical Numerics Inc, Sterling, VA) was used to compute standard deviation maps, select and visualize locations of arterial voxels, and compute the AIF.

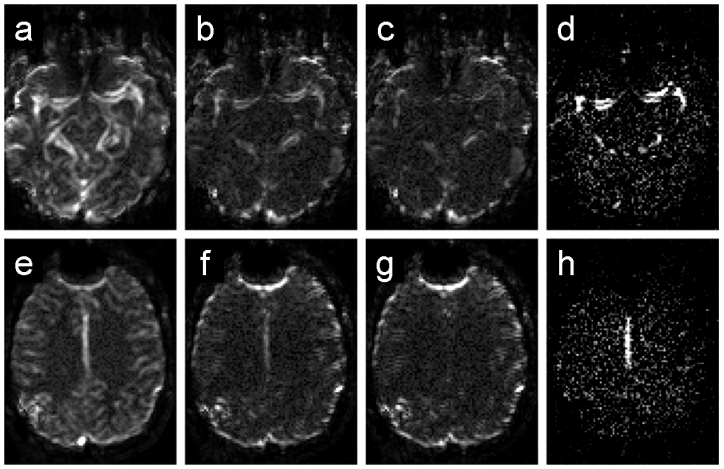

Fig1. SD maps at the level of the MCA and ACA. SD of entire time course (a,e) baseline plus initial 2 seconds of bolus (b,f) baseline (c,g) and difference (d,h) show selectivity of method for arterial voxels.

RESULTS: Standard deviation (SD) maps of the entire time course showed high signal in expected locations of vasculature as well as CSF (Fig. 1a,e). To eliminate venous and parenchymal contributions, the bolus arrival time was computed from the whole brain time course, and SD was calculated from the baseline plus the initial rise after bolus arrival (3-6 seconds or 2-4 time points) (Fig 1b,f). This SD map included arterial voxels plus "noise voxels" largely representing CSF, eyes, edges, and metal artifacts (Fig 1c,g). Subtracting this baseline SD from the SD of the baseline plus initial rise eliminated those voxels which had high baseline fluctuation, yielding a map selective for arterial voxels. (Fig1d,h). Adjusting the threshold systematically reduces the number of candidate voxels, (Fig.2a) with relatively minor changes in the AIF (Fig 2 c).

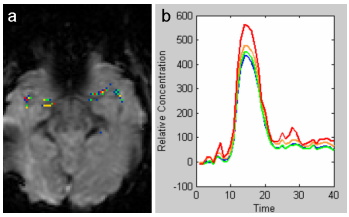

Fig. 2 Location of voxels selected at successively higher thresholds of SD difference map (a) and corresponding AIF (b). (lowest blue, highest red).

Inspection of the time courses of individual AIF voxels revealed that some fraction of these voxels exhibited saturation, blunting the peak of the AIF. To remove the contribution of these voxels, the full width at 95% maximum was inspected at various SD thresholds. If lower thresholds resulted in sharper peaks, the contributions of higher thresholds were eliminated.

DISCUSSION: Our method identified suitable AIFs from routine clinical DSC perfusion studies that were obtained on different scanners with different techniques. Thus, it is suitable for automated computation pf prefusion metrics from clinical data. In contrast to "single best voxel" approaches, saturated voxels are avoid, and the shape of the AIF appears "good'. As many (5-20) voxels are averaged into the AIF, the curve may be suitable for use in direct deconvolution without resorting to using functional forms of the input function (e.g. gamma-variate) and so better reflect vagaries in injection rate and patient hemodynamics.

REFERENCES:

1. Carroll TJ et al. Radiology. 2003 May;227(2):593-600.