Thresholding Artefacts in sSVD and oSVD Deconvolution

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Introduction: Deconvolution methods are widely used in perfusion-weighted imaging (PWI) [1,2] for obtaining CBF, CBV and MTT, but are sensitive to thresholding [3]. Conventionally a single threshold value is used under assumption of uniform SNR in the imaged brain. As we have found SNR of dynamic EPI images to range from 20 to 120 among voxels within an imaged brain, we studied the influence of thresholding on perfusion maps using standard singular value decomposition (sSVD) [1] as well as circular SVD (oSVD) [2].

Objective: Comparison of the influence of thresholding in sSVD and oSVD in typical clinical perfusion data.

Methods: *Monte Carlo Simulations*: We generated 500 concentration time curves for cerebral blood flow between 10 and 70 ml/100g/min in 10 ml increments, assuming an exponential residue function (CBV=4%). Simulations were repeated for SNR = 20, 60, 100. We determined the optimal threshold (P) that minimized the average quadratic error between true and estimated flow relative to true flow.

Clinical MRI: Standard bolus tracking Gradient Echo (GRE) PWI using Gadovist® 1.0 M (Schering) was performed in a healthy female (57 y.o.) on a 1.5T GE Signa LX scanner. We obtained 15 axial slices with a spatial resolution of 1.6x1.6x6mm. Average whole brain pre-bolus (apb) SNR was computed and MTT maps calculated using sSVD and oSVD with corresponding optimal thresholds (P_{oSVD} and P_{sSVD}) determined by the simulations. To asses the influence of suboptimal thresholding we also computed MTT maps with thresholds optimized for SNRs less than 2 sd from apbSNR.

Results: P_{sSVD} and P_{oSVD} for different SNRs are shown in Table 1. The apbSNR of our clinical MRI data was 69 ± 39, and we therefore used the P_{sSVD} and P_{oSVD} determined for SNR 60 in the simulations as optimal thresholds. In Figure 1.a,b we show MTT_{20} subtracted from MTT_{60} for s/oSVD (MTT_x being the map generated using a threshold optimized for SNR=X). For comparison we also show the difference between the optimal sSVD and oSVD MTT maps (Figure 1.c). We summarized the differences between MTT maps (with different thresholds) by averaging MTT values across all voxels in the imaged brain (ΔMTT_{mean}) (Table 2).

SNR	P_{sSVD}	P_{oSVD}
20	0.240	0.106
60	0.080	0.154
100	0.060	0.168

Table 1: Optimal thresholds for different SNRs

Discussion: Table 1 indicates substantial change in P_{sSVD} across the SNR range in agreement with Liu et al [3] whereas oSVD is less sensitive to the choice of P_{oSVD}. Figure 1.a shows a systematic overestimation of MTT in the posterior circulation area when using the P_{sSVD} optimized for SNR=20. Poorly optimized P_{sSVD} (over-regularization) hence biases MTT and CBF values by amplified delay sensitivity. We note that the corresponding oSVD MTT maps exhibit no systematic variation.

For optimized thresholds oSVD produces slightly higher MTT values compared to sSVD. Table 2 confirms that sSVD estimates are sensitive to thresholding across SNR range while oSVD is mostly sensitive to over-regularization.

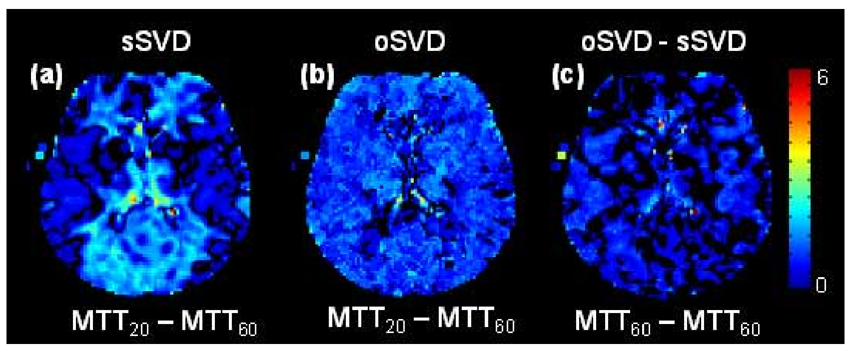

Figure 1: MTT subtraction maps

ΔMTT_{mean}	sSVD (sd)	oSVD (sd)
$MTT_{60} – MTT_{20}$	- 0.85 (0.78)	- 0.86 (0.54)
$MTT_{60} – MTT_{100}$	0.43 (0.51)	0.13 (0.25)

Table 2: MTT difference averaged over whole brain

Conclusion:

Suboptimal uniform thresholding biases oSVD and sSVD perfusion maps and amplifies delay sensitivity for sSVD. Voxel by voxel thresholding is necessary for oSVD as well as sSVD.

References:

[1] Østergaard,L: MRM 36:715-25, 726-36, 1996;
[2] Wu,O: MRM.,50:164-174,2003; [3] Liu,HL: MRM.,42:167-172,1999.