The Robustness of DSC-PWI for Acute Stroke Imaging; Timing is everything: The Vanishing Perfusion Abnormality.

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Background: In patients with acute ischemic stroke, millions of neurons die by the minute. For those who are eligible for thrombolytic therapy, the duration of diagnostic DSC-scans are therefore reduced to a minimum. This study shows that this practice may lead to underestimation of the perfusion abnormality, and therefore the therapeutic target. The degree of underestimation is investigated for three different deconvolution techniques.

Methods: 73 acute stroke patients with a semi-automatically outlined TTP abnormality of between 100 and 200 ml were examined. The slice with the maximum lesion volume was chosen for further analysis. The time of the input-function peak, TTP_{input}, was operationally defined as the minimum scan-duration. For each scan duration, ranging from TTP_{input} to the patient's actual scan duration, perfusion metrics were estimated using oSVD[1], sSVD[2], and a vascular model[3]. The relative MTT (rMTT) was calculated in all voxels by subtracting the mean of the contral-lateral side. The volume within the TTP abnormality with rMTT > 2s was determined for each scan duration and normalized with this volume at full scan duration. This relative abnormality volume is referred to as V^{2s}.

Results: One patient example is shown in figure 1. The perfusion abnormality is not visible for the shortest scan- durations. It is also evident that the abnormality is visible earlier when the vascular model is used for deconvolution. Note that high intensity voxels appear when the scan-duration is very short, especially for oSVD.

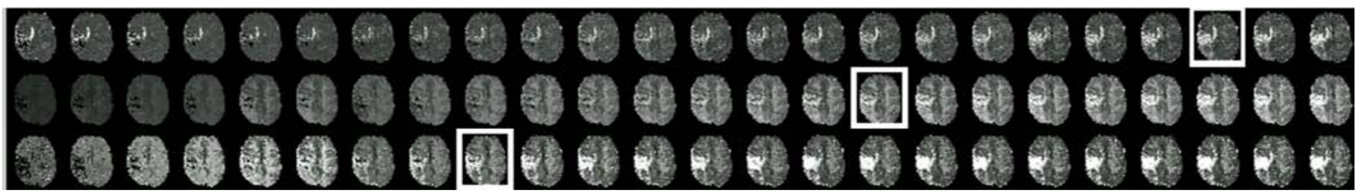

Figure 1: MTT maps as function of measurement duration. Upper row: oSVD. Middle row: sSVD. Bottom row: vascular model. It is apparent that the perfusion abnormality is first seen using the vascular model approach. T^{min} where V^{2s}=90% is marked with squares.

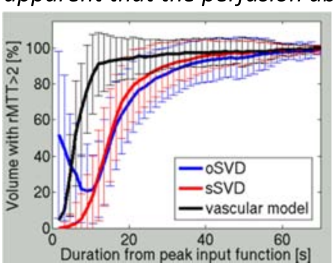

Fig. 2: The relative abnormality volume, V^{2s}, as a function of measurement duration.

The relative abnormality volume, V^{2s}, as a function of measurement duration is shown for all patients in figure 2. Note that the curve approaches 100% faster for the vascular model, and that V^{2s} of 90% is reached earlier with this method. Figure 3 shows for all patients the scan-duration T^{min} at which V^{2s} exceed 90%. The average required scan-duration was 18s for the vascular model, 33s for oSVD and 29s for sSVD. In order to reach T^{min} for 95% of the patients, the scan-duration had to be at least 57 seconds for oSVD, 50 seconds for sSVD, and 39s for the vascular model.

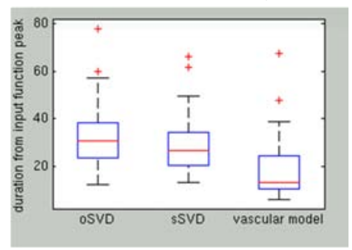

Fig. 3. The scan-duration, Tmin, where V^{2s}=90%.

Discussion: Deconvolution techniques that make no *a priori* assumptions on the tissue response to the measured arterial input are poorly suited for inferring reasonable perfusion estimates when scan-duration is very short. In addition, model-free deconvolution techniques are sensitive to the truncation and poor apodization of signal curves when MRI acquisitions stop mid-bolus. The latter is thought to explain the high-frequency noise in the parametic maps (cf. Fig.1. oSVD). Meanwhile, the parametric model is more robust as it uses smooth priors to describe the residue function. Therefore, MTT estimates using model-dependent approaches appear more robust under conditions of short scan-duration.

Conclusion: The MTT abnormality may be overlooked if scan-durations are too short. From this study, it is recommended to image at least 1 minute after peak of bolus in the arterial input function in order to robustly detect perfusion lesions in 95% of acute stroke patients. With the additional need for 10-12 baseline images, and the inherent variability in bolus arrival time from the time of antecubital contrast injection, we recommend a total scan length of 90-120 seconds in line with the general consensus[4].

References: [1]Wu MRM 2003;50(1):164-74. [2]Ostergaard MRM 1996;36(5):715-25. [3]Mouridsen Neuroimage 2006;33(2):570-9. [4]Wintermark Stroke 2008;39(5):1621-8.