Perfusion Imaging: Bolus truncation alters penumbral status of acute stroke patients. Using a vascular model reduces this effect

Irene Klærke Mikkelsen[1], Lars Riisgaard Ribe[1], and Leif Østergaard[1]
[1]*Center for functionally integrative neuroscience, Aarhus University, Aarhus, Denmark*

Target Audience: Neuroradiologists, technologists, and physicists conducting or analyzing acute stroke perfusion imaging

Pupose: In acute stroke patients, the penumbra is tissue-at-risk of dying. The imaging marker for the penumbra is the mismatch between abnormal regions on perfusion-weighted images (PWI) and diffusion-weighted images (DWI). The PWI-abnormality is affected by imaging duration, since imaging at short duration may fail to capture the entire passage of contrast agent through the affected areas. The purposes were to quantify the effect of such *bolus truncation* (BT), to compare perfusion algorithms under BT, and to determine a minimum scan-time criterion.

Methods: Quantifying Bolus Truncation: We simulated BT in 73 acute stroke patients with large (100-200ml) perfusion abnormality. Imaging duration was increased from arterial time-to-peak (TTP_{AIF}) to the full scan duration. The perfusion abnormality was defined as the region with mean-transit time (MTT) more than 1.78s[1] longer than the contra-lateral side (see fig. 1). The perfusion abnormality and penumbral volumes were calculated for each simulated scan-duration.

Compare Perfusion Algorithms: In the above, MTT maps were calculated using standard singular-value decomposition (sSVD)[2], circular SVD (oSVD)[3], and the vascular-model algorithm (VM)[4], see fig. 1. The number of missing penumbras was compared.

Determine minimum scan-time criterion: For each image voxel, the time-to-conversion (TTC) was determined using the series of MTT maps: TTC was defined as the imaging duration, where the classification of that voxel changed from normal to abnormal (see fig. 1). Maps of TTC were compared to maps of time-to-upslope (TTU) and time-to-downslope (TTD) of the concentration curve (see fig. 2) in order to determine if TTU or TTD could be used to predict TTC.

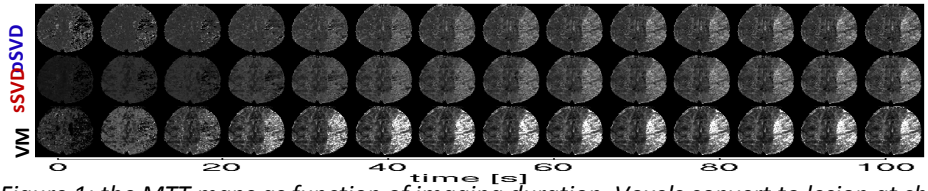

Figure 1: the MTT maps as function of imaging duration. Voxels convert to lesion at shorter imaging duration using VM (buttom row) compared to oSVD (top) and sSVD (middle row).

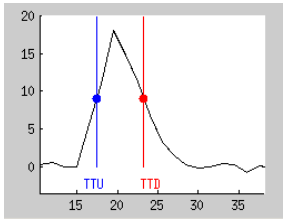

Fig. 2: The time points, where the concentration is half it's peak value, are named TTU and TTD on the up- and down-slope.

Results: The number of penumbras being overlooked decreased with imaging duration (table 1). VM detected penumbras at shorter scan duration. The average time difference between TTU and TTC was 11.6s, 10.5s and 3.5s, respectively, for oSVD, sSVD and VM. The maximum delay was 16s. The TTC - TTU was fairly uniform over voxels, IQR= 2s, whereas for TTD – TTC, IQR was 8.

Duration from peak aif	oSVD	sSVD	VM	Out of
9 s	42	50	12	62
15 s	22	20	4	62
21 s	12	9	1	61
30 s	3	1	1	58

Table 1: Number of patients where the penumbra was NOT detected as a function of duration.

Figure 3. TTU +12s best mimics the time-point where the lesion becomes visible.

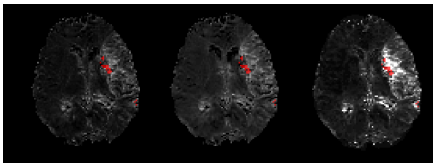

Figure 4: The TTU criterion used to indicate areas of poor image quality.

Conclusion: Penumbral areas may go undetected with insufficient imaging duration. The VM algorithm is less sensitive to bolus truncation. The TTU criterion suggests that the MTT perfusion abnormality is visible 16s after up-slope of the concentration curve. A data quality map may show voxels where imaging duration was shorter than the TTU criterion (see fig. 4).

References [1]Christensen Stroke. 2009;40(6):2055-61.[2]Ostergaard MRM. 1996;36(5):715-25. [3]Wu MRM 2003;50(1):164-74.[4]Mouridsen NeuroImage. 2006;33(2):570-9.