Correlation-based temporal similarity mapping of DSC-MRI data in patients with asymptomatic unilateral high-grade carotid stenosis

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Purpose
- high-grade internal carotid artery stenosis (ICAS) is a common cause of ischemic stroke
- good results in detecting vascular disease using dynamic susceptibility contrast (DSC) MRI
- major research objective: development of quick and easy methods for the analysis of DSC-MRI data
- recent suggestion: iterative correlation-based analysis methods for MRI data of stroke patients introduced by Song et al.2

Patients
- 20 patients (71.2±6.4y, 15 male)
  - high-grade unilateral ICAS (>70% according to NASCET criteria)
  - or occlusion

DSC-MRI @ 3T
- single-shot GE EPI,
  - TE/TR/a = 30 ms/1516 ms/60°
  - voxel size 2x2x3.5mm³
  - 26 slices
  - 80 repetitions
  - bolus of 15-20ml Gd-DOTA (after a pre-bolus)

Methods: Correlation analyses
- Data analysis used SPM126 and custom MATLAB programs6,6
- After preprocessing, Pearson correlation was performed using an iterative approach similar to Song et al6 (method M1)
  - initialization with mean brain time course (TC)
  - six iterations with supra-threshold brain voxels (r > 0.6)
- different reference TCs with short time to peak (TTP) (methods M2 – M5; see Fig. 1)
  - Subtraction method (M5) calculated each voxel’s TTP difference to the minimum TTP in GM (as obtained from the M2 reference TC)
  - Comparison of regions with prolonged TTP to volumes with reduced CCs for methods M1-M4 and TTP subtraction maps (M5)
  - Quantification of detected volumes by applying appropriate thresholds to the TTP, CC and subtraction maps (see Fig. 2)

Results
- Figure 3 shows examples of two patients (A, B) where correlation and subtraction analysis revealed areas with low CCs corresponding reasonably well to areas with prolonged TTP.
- M1 and M3 showed good or acceptable results in all patients, M2 in 75%, M4 in 95%, and M5 in 90% of all patients (visual rating with regard to spatial congruency; rater MW).
- M4 identified the largest lesion regions (+7.5%), M5 the smallest (-5.1%) (Table 1).
- Challenges:
  - low CC values of M1 also detected regions with short TTPs in addition to prolonged TTPs,
  - M2 completely failed or yielded poor CC-maps in one or four patients, respectively.
  - AIF-detection employed for M4 reliably found good quality TCs with shortest TTP in all patients, low-CC volumes tended to be larger than the reference region (Table 1).
  - thresholding CC-maps for performance analyses was difficult in some patients due to poor image quality or nearly uniform CC-values (=1.0, i.e. homogenous TTP)

Discussion & Conclusion
- All methods (except M2) successfully identified ≥ 90% of regions with prolonged TTP
- Overall, the results were promising but several issues remain:
  - the iterative method (M1) shows precision deficits since low CCs could also mean short TTPs
  - M2 is highly sensitivity to noise, producing poor results in 25% of all patients and thus, appears not suitable for broader use
  - correlation with the AIF (M4) tended to identify larger regions than the TTP-based reference
  - the subtraction method (M5) failed in two patients with only slightly prolonged TTPs, but revealed excellent congruence with the visually identified TTP regions in 18 patients.
  - M5 is by far the fastest method with a processing time of 18±5 sec compared to 686±12sec (M1), 235±13sec (M2), 130±11sec (M3), 119±4sec (M4) [Lenovo ThinkPad X201 with Intel® Core™ i5 CPU, 8GB RAM, 64 bit Windows 10].
  - with further methodological improvements, these techniques may provide a quick clinical assessment of perfusion status in the future.

Table 1: Patient averages (mean ± standard deviation (SD)) of region volumes with prolonged TTP and reduced correlation coefficients (CCs) as identified by methods M1 – M5

<table>
<thead>
<tr>
<th>Method</th>
<th>CCs</th>
<th>TTP Region with Prolonged TTP</th>
<th>M1 (Pearson auto.)</th>
<th>M2 (min. TTP GM)</th>
<th>M3 (&lt; 0.5% in max. TTP in GM)</th>
<th>M4 (AIF)</th>
<th>M5 (subtraction method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>36.8 ± 11.0%</td>
<td>34.3 ± 7.7%</td>
<td>39.1 ± 11.9%</td>
<td>33.5 ± 7.5%</td>
<td>28.9 ± 12.3%</td>
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<tr>
<td>M2</td>
<td>36.8 ± 8.4%</td>
<td>34.3 ± 7.7%</td>
<td>39.1 ± 11.9%</td>
<td>33.5 ± 7.5%</td>
<td>28.9 ± 12.3%</td>
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<tr>
<td>M3</td>
<td>36.8 ± 11.0%</td>
<td>34.3 ± 7.7%</td>
<td>39.1 ± 11.9%</td>
<td>33.5 ± 7.5%</td>
<td>28.9 ± 12.3%</td>
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</tr>
<tr>
<td>M4</td>
<td>36.8 ± 11.0%</td>
<td>34.3 ± 7.7%</td>
<td>39.1 ± 11.9%</td>
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<td>M5</td>
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