Diagnostic improvement from average image in acute ischemic stroke

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Introduction

• Perfusion CT (pCT) :  
  Se = 80%, Sp = 95 % (1) in acute stroke diagnosis

• Diagnostic accuracy depends on : stroke  
  size, location and etiology (1,2)

• False negative examinations :  
  Posterior fossa stroke, border zone infarcts, microvascular  
  stroke (1,2,3)

1 : J.M. Biesbroek et al., Cerebrovasc Dis 2013  
2 : T. Hana et al., The Journal of Medical Investigation 2014  
3 : R. Mangla et al., Emerg Radiol. 2014
Introduction

• Average image (AI):
  - \( \sum \text{voxel attenuation} / \text{Number of acquisitions of the slice} \)
  - « Average voxel enhancement »
  - Good spatial and contrast resolution (basal ganglia, BG)
  - Provided by commercial software
Purpose

- **Primary objective**
  Evaluate AI maps contribution to acute (< 6h) ischemic stroke diagnosis

- **Secondary objectives**
  - Evaluate AI maps contribution to BG necrosis diagnosis
  - Evaluate interobserver agreement
  - Determine attenuation thresholds
Materials and methods

• Patients:
  - 98 consecutive patients
  - symptoms (onset <6h) suggesting an acute ischemic hemispheric stroke

• Multimodal CT
  - General Electric Lightspeed VCT 64-Slice CT Scanner
  - Non contrast CT (NCCT)
  - pCT (GE perfusion protocol) with BG coverage
  - CT angiography

• MRI
  - Siemens MRI 1.5 T
  - DWI, FLAIR, T2 GE, 3D TOF
Materials and methods

• Image processing
  - Advantage Windows 4.5 (GE)
  - Software : CT perfusion 4D (GE)
  - Perfusion maps :
    MTT, CBV, CBF, Tmax
  - Relative thresholds :
    145% MTT (4)
    60% CBV (5)

4 : A. Bivard et al., Radiology 2013
5 : M. Wintermark et al., Stroke 2006
Materials and methods

- Interpretation
  - 2 independent observers
  - 2 independent interpretations:
    - First blinded of AI maps
    - Then considering it
- Recorded data:
  - Presence of acute stroke, arterial territory involved
  - Disturbed perfusion parameters
  - BG necrosis
  - Attenuation in normal and injured BG => ratios
- MRI within 3 to 5 following days

✓ Attenuation in normal and injured BG => ratios

• MRI within 3 to 5 following days
Example

67 years old patient, right hemiplegia and oculomotor dysfunction
Results: stroke

Without AI

<table>
<thead>
<tr>
<th>MRI</th>
<th>Stroke</th>
<th>No stroke</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>pCT</td>
<td>63</td>
<td>5</td>
<td>68</td>
</tr>
<tr>
<td>No stroke</td>
<td>16</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>79</td>
<td>19</td>
<td>98</td>
</tr>
</tbody>
</table>

Se = 79.7 %
Sp = 73.7 %

With AI

<table>
<thead>
<tr>
<th>MRI</th>
<th>Stroke</th>
<th>No stroke</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>pCT</td>
<td>67</td>
<td>5</td>
<td>68</td>
</tr>
<tr>
<td>No stroke</td>
<td>12</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>79</td>
<td>19</td>
<td>98</td>
</tr>
</tbody>
</table>

Se = 84.8 %
Sp = 73.7 %
## Results: BG necrosis

### Without AI

<table>
<thead>
<tr>
<th></th>
<th>MRI</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Necrosis</td>
<td>No necrosis</td>
</tr>
<tr>
<td>pCT Necrosis</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>No necrosis</td>
<td>22</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>44</td>
<td>54</td>
</tr>
</tbody>
</table>

\[
\text{Se} = 50 \% \\
\text{Sp} = 100 \%
\]

### With AI

<table>
<thead>
<tr>
<th></th>
<th>MRI</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Necrosis</td>
<td>No necrosis</td>
</tr>
<tr>
<td>AI Necrosis</td>
<td>37</td>
<td>3</td>
</tr>
<tr>
<td>No necrosis</td>
<td>7</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>44</td>
<td>54</td>
</tr>
</tbody>
</table>

\[
\text{Se} = 84.1 \% \\
\text{Sp} = 94.4 \%
\]
Results : thresholds

• Lenticular nuclei
  \( R < 0.94 \) (Se = 95.6\%, Sp = 100\%)

• Caudate nuclei and thalami
  \( R < 0.95 \) (Se = 97.8\%, Sp = 96.2\%)

• Youden indices > 0.9
Results

• Interobserver agreement
  - junior neuroradiologist vs. experienced neuroradiologist
  - Excellent reproducibility for acute stroke diagnosis without and with AI maps: \( \kappa = 0.86 \) and \( \kappa = 0.83 \)
  - Excellent reproducibility for BG necrosis diagnosis using perfusion maps: \( \kappa = 0.84 \)
  - Good reproducibility for BG necrosis diagnosis on AI map: \( \kappa = 0.67 \)
Discussion

• Stroke diagnosis:
  - Se = 79.7%, consistent with previously reported data (1)
  - Low specificity of 73.7% (1) : 3 TIA included
  - AI maps provided 4 additional diagnoses of stroke :
    Se = 84.8%

• BG necrosis
  - AI sensitivity > CBV sensitivity : 84.1 % vs. 50 %
  - AI has high specificity (94.4 %)
  - Thresholds differentiating necrosis from normal attenuation

1 : J.M. Biesbroek et al. Cerebrovasc Dis 2013
Discussion

• AI shows necrosed lesions in BG:
  - AI shows the average enhancement of parenchyma (first pass and recirculation)
  - These lesions were not hypoattenuating on NCCT: hypoattenuation on AI was the consequence of weak/absent enhancement
  - Lesions identified by AI showed restricted diffusion and were hyperintense on FLAIR
Conclusion

• AI map:

✓ Increased pCT sentivity to acute stroke diagnosis, showing BG necrosis
✓ Has good specificity and good interobserver agreement
✓ Is provided by commercial software
✓ Without additional post processing
1. Diagnostic Accuracy of CT Perfusion Imaging for detecting Acute Ischemic Stroke: A Systematic Review and Meta-Analysis. 


3. CT perfusion in acute stroke: Know the mimics, potential pitfalls, artifacts, and technical errors. 

   A. Bivard et al. Radiology: Volume 267: Number 2—May 2013

5. Perfusion-CT Assessment of Infarct Core and Penumbra: Receiver Operating Characteristic Curve Analysis in 130 Patients Suspected of Acute Hemispheric Stroke 