Prevalence of cerebrovascular reserve impairment in patients with severe intracranial stenosis

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Objectives

• Management of patients with SIAS remains controversial Chimowitz NEJM 2013

• Better characterization of the risk of hemodynamic stroke would be helpful Yakota Stoke 1998

• BOLD fMRI to hypercapnic challenge has been proposed to identify impaired cerebrovascular reserve (CVR BOLD fMRI) as a safe and feasible method Spano Radiology 2013

• Prevalence of impaired CVR in patients with anterior SIAS
Materials and methods

• Between 2011 and 2016, 66 patients referred for stroke with SIAS were examined using CVR BOLD fMRI

• Data were compared to controls *Boudiaf J Neuroradiol 2015*

• MRI procedure (3T)
  – Anatomical volumes: 3DT1 FFE / 2D FLAIR / TOF MRA
  – Basal perfusion using DSC
  – BOLD fMRI: T2* GE SSH-EPI
  – Hypercapnic challenge (8%)
    • Block-design: [air (1’) – hypercapnia (2’) – air (1’)] x 3
    • Total duration: 12 minutes
Data analyses

- MATLAB - SPM 12
- Coregistration – Realignment – Segmentation & MNI normalization – Spatial smoothing (6mm)
- GLM: EtCO2 physiological regressor
- ROI analysis
  - Set of cannonical ROIs
  - GM/WM segmentation (smooth 6mm)
  - → set of individual GM ROI
- \( LI_{MCA} = \frac{(CVR_{left} - CVR_{right})}{(CVR_{left} + CVR_{right})} \)
- Data compared to 100 volunteers’ study *Boudiaf J Neuroradiol 2015*
Results

- Among 66 patients referred for stroke with SIAS
  - 46 patients (14 females; 62.2±14.9 years)
    - Unilateral SIAS of internal carotid (n=25) (R/L=13/12)
    - Unilateral SIAS of middle cerebral artery (MCA) (n=21) (R/L=12/9)

- No adverse effect

- Physiological regressor 29/46

- Normal $|L_{\text{MCA}}| < 0.08$
Results

- Among patients with ICA stenosis
  - $|\text{LI}_{\text{MCA}}| = [0.01 - 1.11]$
  - 14 patients out of 25 had an abnormal $|\text{LI}_{\text{MCA}}| \geq 0.08$

- Among patients with MCA stenosis
  - $|\text{LI}_{\text{MCA}}| = [0.01 - 0.29]$
  - 12 patients out of 21 had an abnormal $|\text{LI}_{\text{MCA}}| \geq 0.08$

26 patients out of 46 (57%) had impaired CVR
Results

Correlation CVR – CBF
R=0.86 (p<.001)

Correlation CVR – CBV
R=-0.49 (p<.001)
M 65yo, Right MCA  

BOLD CVR: IL = -0.01

DSC CBF: IL = 0.04
Laterality Index from BOLD functional MRI study of the cerebral vasoreactivity to hypercapnia

Right impairment

Left impairment

Regions Of Interest

Vascular territories of the cerebral arteries used for IL determination

"Radiological" convention, the left side of the image corresponds to the right side of the brain.

Posterior cerebral artery - Anterior cerebral artery - Middle cerebral artery

Posterior inferior cerebellar artery - Superior cerebellar artery

Superimposition

Lobes of the brain used for IL determination

"Radiological" convention, the left side of the image corresponds to the right side of the brain.

Occipital lobe - Parietal lobe - Temporal lobe - Insular lobe

Frontal lobe - Cingulate cortex - Thalamus - Striatum
W 37yo, Right MCA  rufs110216

BOLD CVR: IL = 0.24

DSC CBF: IL = 0.09

Parametric maps: 
- Cerebral Blood Flow in A. U.
- b weight values in D(%BOLD) / EtCO2 (mmHg)

"Radiological" convention, the left side of the image corresponds to the right side of the brain.
Laterality Index values for rufs110216 against the box and whisker plot for a reference population.

Vascular territories of the cerebral arteries used for IL determination:
- Posterior cerebral artery
- Anterior cerebral artery
- Middle cerebral artery
- Posterior inferior cerebellar artery
- Superior cerebellar artery

Lobes of the brain used for IL determination:
- Occipital lobe
- Parietal lobe
- Temporal lobe
- Insular lobe
- Frontal lobe
- Cingulate cortex
- Thalamus
- Striatum

Right impairment

Left impairment
Conclusion

- In our series, CVR impairment occurs in 57% of patients referred for stroke with anterior SIAS

- Downstream SIAS, impaired CVR
  - Negative correlation with CBV
    - Basal vasodilation (autoregulation)
  - Positive correlation with CBF
    - Insufficient vasodilation (chronic low grade ischemia)
  - In line with Bouvier et al. Hum Brain Mapp 2015 (12 cases)

- Therapeutic strategy should take into account CVR information in order to better identify patients at risk of hemodynamic stroke

- New SAMMPRIS study?
Thank you for your attention
Perspectives

- For better quantification, individual physiological regressor ought to be implemented...

and better recorded..