Quantitative Susceptibility Mapping in Ischemic Stroke Patients

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Introduction

Quantitative Susceptibility Mapping (QSM) is a novel post-processing method for gradient echo magnetic resonance imaging (MRI) (1). In acute stroke, it has shown that QSM is able to detect venous structures with increased susceptibility values in the ischemic hemisphere (2). QSM can help to estimate oxygen content of blood vessels, which is an important parameter in brain ischemia and reperfusion. Our goal was to analyze susceptibility signals of cortical veins in stroke patients to gather more information about the infarct and its collateral supply after stroke.

Methods

- Data from 13 stroke patients with successfully recanalized middle cerebral artery (MCA)-M1 segment occlusion were collected.
- MRI images acquired 24-72h after thrombectomy were analysed using ImageJ (3).
- The following clinical variables were collected: age, sex, cardiovascular risk factors, stroke etiology, National Institute of Health Stroke Scale (NIHSS) on admission and stroke-to-needle time.
- Outcome measures were: flow within the MCA-M1 after recanalization determined by duplex sonography, NIHSS after 24 hours, modified Rankin Scale (mRS) after 3 months, and infarct volume after recanalization measured on diffusion-weighted imaging (DWI) at 24-72h.
- QSM signals of veins were explored and compared between stroke core, boundaries of the ipsilateral MCA territory and contralateral MCA territory using the nonparametric Wilcoxon signed-rank test.

Fig.1) Demonstration of quantitative susceptibility maps of a stroke patient. The DWI (A) shows the lesion on the left ischemic hemisphere. (B) shows the susceptibility weighted image (SWI). The quantitative susceptibility map (QSM) is depicted in (C). Veins with high deoxyhemoglobin content show high susceptibility values on QSM (red arrows). (D-F) show cortical veins on QSM within the different territories; stroke in red, infarct border in cyan, contralateral MCA in magenta. The stroke territory is delineated in orange.

Conclusions and Outlook

After recanalization of MCA-M1 territory stroke, no prominent vessels with high susceptibility were found, but low venous susceptibility signal within vessels in the infarct area, likely caused by low deoxyhemoglobin content. This might indicate either normalized oxyhemoglobin levels after recanalization or poor oxygen extraction in the infarct based on tissue damage. Further exploration of the QSM signal and correlation with infarct size and outcome will reveal which of these processes underlie the observed signal changes and its prognostic value for stroke recovery.

References:
1. Vaas et al. 2017, Vascular and Tissue Changes of Magnetic Susceptibility in the Mouse Brain After Transient Cerebral Ischemia. *Transl Stroke Res* 2017, in press. 2. Xia et al. 2014, Decreased oxygen saturation in asymmetrically prominent cortical veins in patients with cerebral ischemic stroke. *Magn Reson Imaging* 32(10): 1272-1276 (2014). 3. Schneider, C. A.; Rasband, W. S. & Eliceiri, K. W., NIH Image to ImageJ: 25 years of image analysis, *Nature methods* 9(7): 671-675 (2012)

Results

Table 1: Patient characteristics

	Stroke patients (n = 13)
Demographic data	
Age, y (range)	68 (45-87)
Female, n (%)	5 (38)
Risk factors, n (%)	
Diabetes mellitus	3 (23)
Dyslipidemia	7 (54)
Smoking	4 (31)
Hypertension	8 (62)
Coronary heart disease	4 (31)
Atrial Fibrillation	6 (46)
Persistent foramen ovale0	
Prior stroke	1 (8)
Stroke etiology, n (%)	
Large-vessel disease	0
Cardioembolic	6 (46)
Small-artery disease	0
Other cause	1 (8)
Undetermined	6 (46)

Table 1: Hypertension, dyslipidemia and atrial fibrillation were the most common vascular risk factors. Most strokes were either cardioembolic or due to an undetermined cause.

Table 2: Treatment and Outcome characteristics

	Stroke patients (n = 13)
Flow MCA-M1 [mmHg], median (IQR)	
Ipsilateral systolic	109 (85-141)
Contralateral systolic	104 (83-120)
Ipsilateral diastolic	43 (30-52)
Contralateral diastolic	39 (29-51)
Stroke-to-needle time [min], median (IQR)	
	162 (75-268)
Clinical Scores , median (IQR)	
NIHSS on admission	13 (7-15)
NIHSS after 24h	5 (1-6)
NIHSS difference	8 (4-12)
mRS after 3 months	1 (0-3)
Infarct volume after recanalization [cm ³], median (IQR)	
	25 (12-83)

Table 2: The median NIHSS on admission was 13. 24h after successful recanalization the median NIHSS dropped to 5. Evaluation after 3 months showed good recovery overall with a median mRS of 1. The median infarct volume measured on DWI after recanalization was 25cm³. One patient was excluded from the analysis due to artefacts on QSM images.

Fig.2

Table 3: QSM signals

	Stroke territory	MCA ipsilateral	MCA contralateral	p value
Susceptibility of veins,	0.026 (0.017-0.032)	0.036 (0.030-0.049)		0.013
median (IQR)	0.026 (0.017-0.032)		0.042 (0.034-0.047)	0.013

Fig.2 and Table 3) Comparison of the susceptibility of cortical veins show significantly reduced susceptibility signals within the stroke territory (*median 0.026, IQR 0.017-0.032*) compared to the infarct border (MCA ipsilateral, *median 0.036, IQR 0.030-0.049*), *p=0.013*. Furthermore, the susceptibility of the stroke territory is significantly lower than the signal on the control hemisphere (MCA contralateral, *median 0.042, IQR 0.034-0.047*), *p=0.013*. Note the similarity of QSM signals between the infarct border ipsilateral MCA territory and the contralateral MCA territory.