Histogram analysis of cerebral dynamic susceptibility contrast-enhanced perfusion MRI data in moyamoya arteriopathy and correlation with MRA findings

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Introduction

Moyamoya arteriopathy is defined as progressive occlusion of large intracranial arteries and subsequent formation of basal collateral supply, known as moyamoya vessels. Conventional catheter angiography remains the gold standard in the diagnosis of moyamoya arteriopathy but has been shown to correlate well with MR angiography (MRA) [1]. Recently, dynamic susceptibility contrast-enhanced perfusion MRI (DSC MRI) has been investigated as method of demonstrating haemodynamic compromise in moyamoya disease, using measurements from multiple regions of interest (ROI) placed in different vascular territories [2]. Complex perfusion parameters are difficult to assess in moyamoya disease due to bolus dispersion and delay [3]. We investigate a simple parameter – time to minimum DSC signal intensity (T_{min}) – which does not require an arterial input function or deconvolution analysis. We analysed histograms of T_{min} obtained from complete vascular territories and investigated the correlation of histogram parameters with the degree of vascular compromise shown on MRA.

Methods

12 patients (8 female, 4 male, median age 23 years, range 19 – 41 years) with moyamoya arteriopathy were investigated using DSC MRI (gradient-echo EPI, flip angle (FA) 20^o, TR/TE 1200/40 ms; FOV 26x26 cm, 7 contiguous 5mm slices) and time-of-flight MR angiography (2 slab 3D MOTSA, TR/TE 37/6.9 ms; FA 20^o, FOV 25x18.75 cm; 245x224 pixels, 80x1 mm slices). T_{min} maps (figure 2) were generated using FuncTool software (GE medical systems). As starting point we chose the first image with detectable intracranial loss of signal. Colour maps were transferred off-line to a Unix Workstation for further analysis with DispImage [4]. ROIs were drawn manually around the anticipated vascular territories of the left and right anterior and posterior circulation respectively for a total of 36 vascular territories. MRA moyamoya scores for each separate vascular territory were determined using a system suggested by Houkin et al. [1] yielding scores which ranged from 0 to 8, with 8 representing the most severe vascular compromise. T_{min} Histograms were generated for each ROI (figure 1) and Spearman's rank correlation coefficient calculated respectively for peak height, peak location, SD, skewness, and kurtosis versus MRA moyamoya score using standard statistical software (SPSS 12.0.1).

Results

There was significant negative correlation between the MRA moyamoya score and T_{min} histogram peak height ($r=-0.779$, $p<0.01$), standard deviation ($r=-0.641$, $p<0.01$), and kurtosis ($r=-0.751$, $p<0.01$). The strongest negative correlation was with skewness ($r=-0.818$, $p<0.01$). There was no correlation with peak location ($r=0.241$, $p=0.146$).

Discussion

Excellent negative correlation was found between MRA score and skewness. This is likely to reflect bolus dispersion and delayed wash-in of contrast agent in the vasculature due to the presence of collateral vessels. Negative correlation between MRA score and peak height is likely to be a sign of a wider range of T_{min} caused by increased bolus dispersion in pathology. The lack of correlation between MRA score and peak location is probably due to inter-patient variability in bolus delay. Despite this variability, the remaining T_{min} histogram metrics correlated well with MRA angiographic findings in this patient group and could prove useful for monitoring disease progression and haemodynamic outcomes of revascularisation procedures in patients with moyamoya disease.

References

1. Houkin, K., et al., *Novel magnetic resonance angiography stage grading for moyamoya disease.* Cerebrovasc Dis, 2005. **20**(5): p. 347-54.
2. Togao, O., et al., *Cerebral hemodynamics in Moyamoya disease: correlation between perfusion-weighted MR imaging and cerebral angiography.* AJNR Am J Neuroradiol, 2006. **27**(2): p. 391-7.
3. Calamante, F., et al., *MR perfusion imaging in Moyamoya Syndrome: potential implications for clinical evaluation of occlusive cerebrovascular disease.* Stroke, 2001. **32**(12): p. 2810-6.
4. Plummer, D.L., *Dispimage: a Display and Analysis Tool for Medical Images.* Rivista di Neuroradiologica, 1992. **5**: p. 489-95.

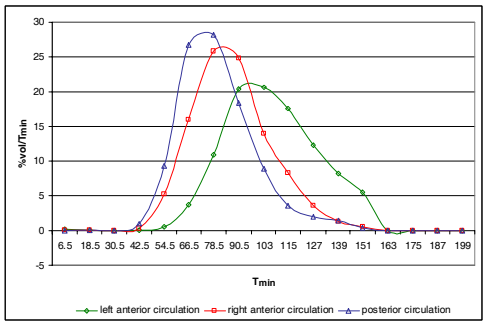

figure 1. T_{min} histogram for left and right anterior and posterior circulation. Positive skewness meaning data is more spread out to the right of the mean.

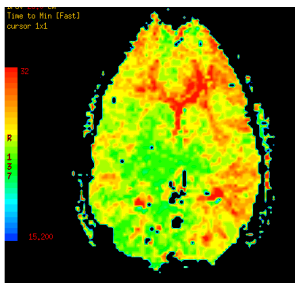

figure 2. T_{min} colour map showing delayed Time to min in the left anterior circulation.

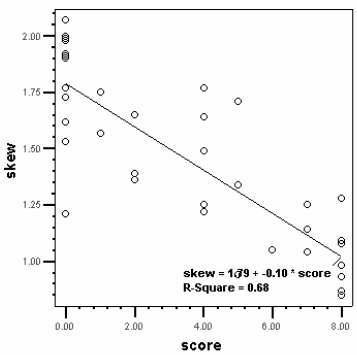

figure 3. Scatter plot showing correlation between moyamoya score and skewness of the T_{min} histogram