Quantitative assessment of cerebrovascular structure after carotid revascularization using intraCranial Artery Feature Extraction (iCafe) Technique

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Synopsis

The aim is to evaluate the change in intracranial arterial vasculature after carotid revascularization using an intracranial feature extraction (iCafe) technique for quantitative analysis of intracranial arteries from 3D time-of-flight magnetic resonance angiography (TOF MRA). Twenty subjects who received carotid revascularization were enrolled and all patients underwent MRA scans three times: before, within 3 days after, and six months after revascularization. The dataset was processed blindly by 4 reviewers using iCafe. Length and volume of intracranial artery and number of intracranial artery branches increased after surgery. This result suggested increased cerebral blood flow after carotid revascularization.

Introduction

Cerebral blood flow increases after carotid revascularization1,2. In some individuals, persistent hyperperfusion may lead to headache, seizure, or intracranial hemorrhage, and carries a poor prognosis. In others, increased perfusion following revascularization may be associated with improvement in cognitive function3. Further investigation into the pathophysiology and mechanisms of change in intracranial vasculature after carotid revascularization is needed to better differentiate patients with poor prognosis from those who will benefit from intervention. The paucity of reproducible, quantitative assessment tools is a major barrier to such studies. An intraCranial artery feature extraction (iCafe) technique, which semi-automatically evaluates vessel structure from 3D TOF MRA images4 could provide quantitative information about changes in vasculature. A 3D quantitative vasculature map can be generated from iCafe and morphometry features of intracranial arteries can be extracted, such as length and radius of arteries. In this study, we analyzed intracranial artery structures from a group of patients at three timepoints using iCafe to evaluate the change of intracranial vasculature after carotid revascularization.

Methods

The study followed local IRB guidelines and informed consent was obtained for all patients prior to enrollment. Twenty subjects who received carotid revascularization were scanned at three timepoints (pre and post intervention and 6 months after the procedure). 3D TOF MRA images were acquired on 3.0T GE scanner. Imaging parameters were as follows: TR/TE = 25/3.5 ms, flip angle = 20°, in-plane resolution = 0.35mm×0.35 mm, slice thickness = 1.4 mm, matrix = 376*277. Four readers reviewed the MRA images using iCafe and one examiner then peer-reviewed their results. Each reviewer conducted processing of all timepoints of one subject throughout to reduce inter-rater bias. A representative case is shown in Figure 1. We analyzed length and volume of total arteries, the right and left side of anterior circulation arteries, radius of the internal carotid and M1 segment of middle cerebral arteries. Paired Wilcoxson test was used to assess the difference of features in each timepoint. $P<0.05$ was considered as statistically significant without adjustment for the number of comparisons. Jmp 13 was used for the statistical analysis.

Results

Table 1 shows a summary of our findings. The total vessel length and volume of intracranial artery increased after the surgical treatment compared to pre treatment (2298 mm vs. 2820 mm, 10262 mm3 vs. 11739 mm3 p=0.0001, 0.02, respectively). However, the length of vessels six months after surgical treatment was shorter compared to post-surgical treatment (2820 mm vs. 2657 mm, p=0.01), although the volume was unchanged (11739 mm3 vs. 11125 mm3, p=0.51). The length of intracranial arteries in both left and right sides post treatment was longer than before treatment. (852.6 mm vs 1036 mm, 763.6 mm vs 988.8 mm, p=0.003, 0.003). The radius of the internal carotid and middle cerebral arteries was unchanged across the three time points, while radius of M1 segment decreased six months after treatment (1.78 mm vs. 1.67 mm, p=0.03). The numbers of branches of intracranial arteries increased post revascularization (73.5 vs. 96.5, 87.5, p=0.0002, 0.01).

Discussion

Findings of this study are consistent with increased intracranial blood flow just after the carotid revascularization in both ipsilateral and contralateral hemispheres based on the increase of length, volume and the number of the branches measured with iCafe. This is the first report that provides quantitative MRA assessment with iCafe for evaluating the influence of carotid revascularization on intracranial vascular structure. These findings demonstrate the potential for utilizing conventional, widely utilized clinical imaging techniques (MRA), and a semi-automated, objective image analysis tool (iCafe) in studies to examine the association between intracranial arterial structure, changes with revascularization, and its effect on cognitive function.

Conclusion

We found that there were significant changes in intracranial vessel length and the number of intracranial vessel branches after carotid revascularization using iCafe. This study also demonstrates the potential future application of iCafe for assessing cerebral blood flow changes after vascular reconstruction.

Acknowledgements

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Figures

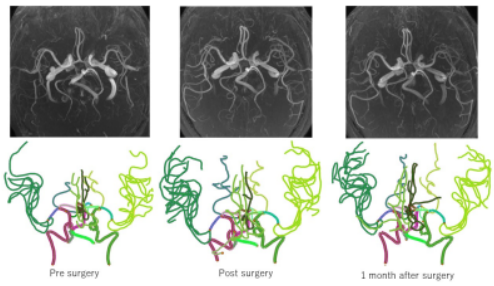

Figure 1. ICafe imaging of representative case

				P value		
	Pre surgical Treatment (1)	Post surgical Treatment (2)	6 month later (3)	(1)-(2)	(2)-(3)	(1)-(3)
Total length of visible vessels (mean, [IQR], mm)	2298 [2042-2504]	2820 [2636-3003]	2657 [2367-2954]	0.0001	0.23	0.01
Total volume of visible vessels (mean, [IQR], mm3)	10262 [9301-11833]	11739 [10780-14019]	11125 [9378-12195]	0.02	0.16	0.51
Total visible vessel length of right anterior circulation (mean, [IQR], mm)	763.6 [701.8-860.8]	988.8 [903.8-1145.7]	977.9 [765.8-1073.9]	0.0003	0.31	0.03
Total visible vessel length of left anterior circulation (mean, [IQR], mm)	852.6 [682.6-944.4]	1036 [878.6-1161.6]	948.7 [785.2-1088.1]	0.003	0.25	0.06
Radius of internal carotid artery (mean, [IQR], mm)	2.4 [2.2-2.52]	2.37 [2.24-2.5]	2.31 [2.16-2.46]	0.83	0.51	0.58
Radius of Middle cerebral artery; M1 segment (mean, [IQR], mm)	1.78 [1.7-1.9]	1.76 [1.67-1.87]	1.67 [1.44-1.79]	0.8	0.2	0.03
Total number of branches (mean, [IQR], n)	73.5 [69-87]	96.5 [82-108.5]	87.5 [78.8-97]	0.0002	0.15	0.01

Table 1 The results of each vasculature changes