RESEARCH PAPER

Anterior choroidal artery ischaemic patterns predict outcome of carotid occlusion

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ABSTRACT

Objective To investigate whether anterior choroidal artery (AChA) territory sparing or AChA infarction restricted to the medial temporal lobe (MT), implying good collateral status, predicts good outcome, defined as modified Rankin Scale 0–2, at discharge in acute internal carotid artery (ICA) occlusion.

Methods The authors studied consecutive patients with acute ICA occlusion admitted to an academic medical centre between January 2002 and August 2010, who underwent MRI followed by conventional angiography. The pattern of AChA involvement on initial diffusion-weighted imaging was dichotomised as spared or MT only versus other partial or full. The association of AChA infarct patterns and good outcome at discharge was calculated by multivariate logistic regression with adjustment.

Results For the 60 patients meeting entry criteria, mean age was 68.3 years and median admission NIH Stroke Scale score was 19. AChA territory was spared or restricted to the MT in 27 patients and other partially involved or fully involved in 33 patients. AChA territory spared or ischaemia restricted to MT only, compared with other partial infarct patterns or full infarct, was independently associated with good discharge outcome (44.4% vs 12.1%, OR 7.24, 95% CI 1.32 to 39.89, p=0.023).

Conclusion In acute ICA occlusion, the absence of AChA infarction or restriction to the MT is an independent predictor of good discharge outcome. Analysis of AChA infarct patterns may improve early prognostication and decision-making.

INTRODUCTION

The prognosis of acute internal carotid artery (ICA) occlusion may be difficult to predict. Patients with acute ICA occlusion may be asymptomatic or experience neurological effects ranging from transient ischaemic attack to devastating stroke.[1] One possible explanation for such variation is that relatively good prognoses may be associated with robust collateral circulation from other arterial sources.

Although one study suggested no evidence that the clinical presentation associated with an ICA occlusion was related to patency of other extra or intracranial arteries to act as collateral pathways,[1] the characterisation of collateral pathways was limited to Doppler ultrasound of the anterior communicating artery, posterior communicating artery and ophthalmic artery.[1] Therefore, the relationship between collateral status and ICA occlusion functional outcome merits further investigation.

The anterior choroidal artery (AChA) is the last branch of the ICA, providing blood supply to the medial temporal lobe (MT), the posterior limb of the internal capsule and the posterior paraventricular area,[2–4] ultimately ending in the choroid plexus.[5 6] Anastomoses exist along the choroidal fissure and within the choroid plexus itself and among the branches of the AChA, lateral and medial posterior choroidal arteries, and splenothalamic artery.[7] It is likely that collateral blood supply may come from these arteries when blood supply from the ICA is blocked, if good collateral flow exists. From an anatomical point of view, this kind of collateral flow is likely to supply the posterior paraventricular area, then the posterior limb of the internal capsule and the MT, which is the farthest area from the collateral flow. On the other hand, early AChA infarction may reflect extensive ICA thrombus including the AChA origin and/or poor collateral status.

Although the volume of baseline diffusion-weighted imaging (DWI) lesions are known to influence outcome in acute ICA occlusion, the predictive role of specific DWI patterns in critical regions such as the AChA remains unknown. We hypothesised that AChA territory sparing or AChA infarction restricted to the MT, implying good collateral status, predicts good outcome, defined as modified Rankin Scale (mRS) 0–2, at discharge in acute ICA occlusion.

METHODS

We studied consecutive patients with acute ICA occlusion evaluated between January 2002 and August 2010, who underwent MRI followed by conventional angiography at an academic hospital. We included patients with ICA occlusions, defined as Thrombolysis In Myocardial Infarction (TIMI)=0 on angiography, regardless of the ICA occlusion site or whether occlusions were found in the middle/anterior cerebral artery. MRI was acquired as per the standard algorithm for acute stroke cases with a protocol including DWI sequences as previously described.[8] Patients with

moyamoya disease were excluded due to the distinct nature of that disorder. Patients who received thrombolytic therapy before baseline MRI were also excluded to avoid confounding. The diagnostic angiograms were performed to determine whether patients were candidates for endovascular recanalisation therapy.

Clinical, radiographic and detailed angiographic data were acquired as part of a prospective registry at our centre. We collected baseline demographic and clinical information for all enrolled participants, including sex, age and cardiovascular risk factors such as hypertension, diabetes mellitus, hyperlipidaemia, atrial fibrillation, smoking, history of stroke, history of coronary heart disease and pre-event medication (eg, antiplatelet, anticoagulant and statin). We also collected stroke characteristics including stroke subtype, presenting National Institutes of Health Stroke Scale (NIHSS) score, time interval from last known well to MRI, time interval from last known well to angiography, procedure used for intervention, symptomatic and asymptomatic intracranial haemorrhage after intervention, duration of admission, recanalisation status after endovascular recanalisation intervention, and mRS score at discharge. Recanalisation was defined as Thrombolysis In Cerebral Infarction (TICI)=2b or 3.

Pattern of AChA involvement on initial DWI was dichotomised as spared or MT only versus other partial or full.[4] Two vascular neurologists who were blinded to the clinical and angiographic variables independently labelled the AChA infarct pattern. Discrepancies were resolved by consensus discussion. The study was approved by the local institutional review board.

The primary outcome measure was avoidance of death or disability at discharge, assessed by dichotomising the mRS at 0–2 versus 3–6. Secondary analyses included avoidance of death or dependence at discharge, assessed by dichotomising the mRS at 0–3 versus 4–6.

Statistical analysis

Statistical analysis was performed using SPSS V.17.0 (SPSS Inc). We tested differences among the groups using the χ^2 test for categorical variables and the Mann–Whitney test for continuous variables. The crude association between admit AChA infarct pattern on DWI and functional outcome at discharge was evaluated by the χ^2 test. The adjusted association between admit AChA infarct pattern on DWI and functional outcome at discharge was calculated by multivariate logistic regression with adjustment of age, gender, baseline NIHSS scores, time between last known well and MRI, intervention procedure, recanalisation status, and factors showing statistical difference in univariate analysis. $p<0.05$ was used to indicate statistical significance.

RESULTS

During this period of time, 15 ICA occlusion patients were excluded from this study because either baseline MRI or conventional angiography was lacking. For the 60 patients meeting study entry criteria, mean age was 68.3 (±16.1) years, median admission NIHSS score was 19 (IQR 14–22), median time from last known well to MRI was 270 min (IQR 210–340) and median time from last known well to angiography was 470 min (IQR 380–600). The inter-rater agreement for labelling AChA infarct pattern was 90% and a consensus discussion was conducted in six patients. Among the 60 included patients, 56 underwent endovascular recanalisation interventions while 4 patients did not due to unfavourable features noted during diagnostic angiography. Among these four patients, two patients belonged to the AChA spared or the MT involved only group while the other two patients belonged to the other patterns of partially involved or fully involved group. AChA territory was spared or restricted to the MT in 27 (45%) patients and other partially involved or fully involved in 33 (55%) patients. Examples of AChA infarct patterns on DWI and their clinical profiles are illustrated in figure 1.

Baseline characteristics and recanalisation status after intervention were not different among the two AChA DWI patterns (table 1). Across all groups, lower baseline NIHSS score and higher current smoking rate were associated with good functional outcome at discharge (table 2). Also, patients with recanalisation after intervention had higher possibility of fair outcome at discharge. The AChA spared or MT involved only, compared with other patterns of partially involved, had higher possibility of good (44.4% vs 12.1%) or fair (51.9% vs 21.2%) functional outcome at discharge.

In the multivariate logistic regression model, AChA spared or MT involved only, compared with other partial infarct patterns

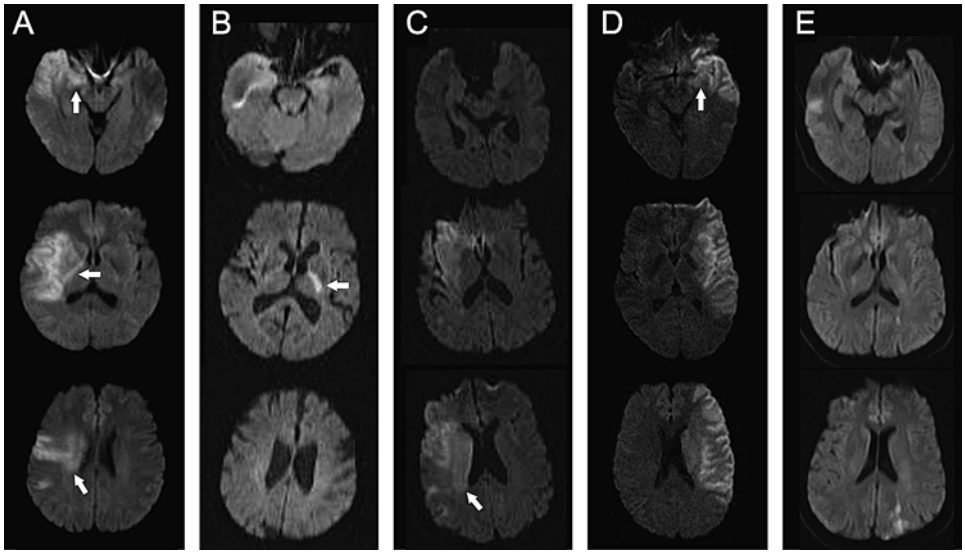

Figure 1 Anterior choroidal artery infarct (AChA) patterns on diffusion-weighted imaging. (A) 46-year-old woman, admit NIHSS (National Institutes of Health Stroke Scale) score 19, AChA territory fully involved (ie, medial temporal lobe, posterior limb of the internal capsule, posterior paraventricular area) (arrows), modified Rankin Scale (mRS) 4 at discharge. (B) 86-year-old woman, admit NIHSS score 20, posterior limb of the internal capsule involved (arrow), mRS 5 at discharge. (C) 38-year-old man, admit NIHSS score 20, posterior paraventricular area involved (arrow), mRS 4 at discharge. (D) 41-year-old man, admit NIHSS score 22, medial temporal lobe involved (arrow), mRS 2 at discharge. (E) 55-year-old man, admit NIHSS score 22, AChA territory spared, mRS 1 at discharge.

Table 1 Characteristics of anterior choroidal artery infarct patterns in internal carotid artery (ICA) occlusion patients

Characteristics	Spare or MT only, n=27	Full or other patterns of partial, n=33	p Value
Age, years	63 (IQR 55–83)	70 (IQR 58–86)	0.436
Male, %	37%	55%	0.203
Baseline NIHSS score	18 (IQR 10–22)	19 (IQR 16–22)	0.546
Time interval			
Last known well to MRI, minutes	275 (IQR 156–360)	270 (IQR 230–381)	0.459
Last known well to angiography, minutes	480 (IQR 350–600)	470 (IQR 380–540)	0.958
Recanalisation after intervention, %	72%	68%	0.929
Type of ICA occlusion			
Cardioembolic	46%	50%	0.798
Large vessel atherosclerosis	23%	23%	1.000
Dissection	8%	6%	1.000
Undetermined	23%	23%	1.000
Stroke risk factors			
Hypertension	67%	74%	0.873
Diabetes mellitus	30%	10%	0.091
Hypercholesteraemia	33%	42%	0.771
Current smoking	26%	16%	0.613
Atrial fibrillation	26%	35%	0.759
History of stroke	4%	6%	1.000
History of CAD	15%	32%	0.152
Pre-event medication			
Antiplatelet	30%	40%	0.455
Anticoagulant	7%	7%	0.599
Statin	23%	17%	0.690
Intervention			
Thrombectomy only	91%	96%	0.430
Thrombolysis + thrombectomy	9%	4%	0.430
Symptomatic ICH after intervention	4%	3%	0.885
Asymptomatic ICH after intervention	7%	24%	0.082
Duration of admission, day	6 (IQR 3–16)	10 (IQR 6–12)	0.201
Final infarct volume, cm^3	60 (IQR 9–160)	125 (IQR 54–172)	0.077

CAD, coronary artery disease; ICH, intracerebral haemorrhage; MT, medial temporal lobe; NIHSS, National Institutes of Health Stroke Scale.

and full infarct, was independently associated with good discharge outcome after adjustment (OR 7.24, 95% CI 1.32 to 39.89, p=0.023). The results were similar when we used fair functional outcome as an endpoint (table 3).

DISCUSSION

Previous studies have largely focused on anatomical distribution, clinical syndromes and the mechanisms of isolated AChA territory infarction,[2 9] yet its relationship with ICA occlusion, a more commonly encountered and devastating disease, has never been explored in a consecutive series of patients. Although baseline AChA DWI patterns were not associated with presenting stroke severity, as indexed by NIHSS score, they did affect functional outcome at discharge. Spared AChA territory or AChA infarction restricted to the MT independently predicted good or fair discharge outcome.

In the current study, all ICA occlusions were confirmed by catheter angiography and the infarct status was universally evaluated by DWI just before angiography. In previous studies, brain CT was used to evaluate AChA infarction but its sensitivity in the hyperacute period is not good.[10] DWI has been shown to be very sensitive to detect infarction in the hyperacute phase of stroke.[11] Furthermore, intra-arterial thrombolysis and/or thrombectomy were applied in almost all patients in this series, increasing its relevance in an era of increasing use of recanalisation interventions.

The different types of AChA infarct patterns and their association with different outcomes may be largely affected by collateral circulation. In the setting of ICA occlusion, blood flow from the posterior cerebral artery via the posterior communicating artery and/or from the contralateral anterior cerebral artery via the anterior communicating artery and the ipsilateral anterior cerebral artery are sources of collateral flow for the occluded ICA.[12 13] In acute ICA occlusion, AChA territory may be spared if the collateral circulation is sufficient. Additional collateral perfusion may arrive via anastomoses. A study showed that retrograde filling of the AChA from the posterior circulation was observed on a vertebral angiogram with occlusion of the proximal AChA or of the ICA.[14] When AChA infarction is restricted to the MT, it may reflect good collateral flow via retrograde filling of the AChA even when the proximal AChA is completely occluded.

Infarct patterns and clinical outcomes following acute ICA occlusion are heterogeneous in this series, as in a previous study.[15] Although overall nearly two-thirds of the ICA occlusion patients in our series had poor outcome (mRS>3 at discharge), more than half with AChA spared or restricted to the MT showed fair or better outcome at discharge (mRS≤3). There may be widespread misunderstanding that acute ICA occlusion is inevitably associated with poor prognosis, and early withdrawal from aggressive care may be implemented pre-emptively. In this series, only five patients withdrew from aggressive care within 5 days and all these patients had poor outcome by discharge. Baseline AChA DWI patterns provide additional

Table 2 Patient profile according to outcome status

Characteristics	Good versus poor outcomes at discharge			Fair versus poor outcomes at discharge		
	mRS ≤2, n=16	mRS >2, n=44	p Value	mRS ≤3, n=21	mRS >3, n=39	p Value
Age, years	60 (IQR 42–80)	71 (IQR 58–85)	0.102	57 (IQR 46–82)	71 (IQR 61–85)	0.055
Male, %	38%	50%	0.559	43%	49%	0.788
Baseline NIHSS score	12 (IQR 8–19)	20 (IQR 17–23)	0.001	17 (IQR 8–22)	20 (17–23)	0.019
Time interval						
Last known well to MRI, minutes	315 (IQR 230–435)	270 (IQR 217–350)	0.323	290 (IQR 210–420)	270 (IQR 217–350)	0.565
Last known well to angiography, minutes	503 (IQR 355–600)	470 (IQR 390–590)	0.931	430 (IQR 360–600)	480 (IQR 425–590)	0.621
Recanalisation after intervention, %	81%	59%	0.218	86%	54%	0.038
Type of ICA occlusion						
Cardioembolic	47%	49%	1.000	35%	55%	0.174
Large vessel atherosclerosis	21%	23%	1.000	26%	21%	0.742
Dissection	7%	7%	1.000	11%	5%	0.594
Undetermined	29%	21%	0.715	32%	18%	0.323
Stroke risk factors						
Hypertension	53%	77%	0.105	60%	76%	0.228
Diabetes mellitus	13%	21%	0.380	20%	18%	0.705
Hypercholesteraemia	27%	42%	0.254	40%	37%	0.648
Current smoking	40%	14%	0.040	35%	13%	0.066
Atrial fibrillation	20%	35%	0.265	20%	37%	0.233
History of stroke	0%	7%	0.301	0%	8%	0.226
History of CAD	13%	28%	0.239	10%	32%	0.081
Pre-event medication						
Antiplatelet	27%	38%	0.223	30%	38%	0.356
Anticoagulant	0%	10%	0.161	0%	11%	0.130
Statin	20%	20%	0.955	20%	19%	0.851
Symptomatic ICH after intervention	0%	5%	1.000	10%	0%	0.119
Asymptomatic ICH after intervention	25%	14%	0.433	19%	15%	0.729

CAD, coronary artery disease; ICA, internal carotid artery; ICH, intracerebral haemorrhage; MT, medial temporal lobe; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale.

information regarding prognosis in acute ICA occlusion, and early withdrawal of aggressive care may be less desirable when favourable AChA DWI patterns exist.

This study has limitations. We used discharge outcomes, rather than final 3-month outcomes, as endpoints in this study. However, disability status (eg, mRS) 1 week after an index ischaemic stroke has been proven to strongly predict final 3-month disability outcome.[16] Also, we did not comprehensively evaluate the collateral status in this study. The purpose of this study was to find a strategy that can be easily applied in daily practice to predict prognosis of acute ICA occlusion, using an imaging pattern parameter that can readily be obtained from qualitative evaluation.

In conclusion, spared or AChA infarction restricted to the MT on baseline DWI independently predicts good or fair discharge outcome in acute ICA occlusion. Analysis of AChA infarct patterns on DWI may improve early prognostication and decision-making.

Table 3 Association between anterior choroidal artery (AChA) infarct pattern and functional outcome at discharge after adjustment

	OR (95% CI)	p Value
Good outcome (mRS 0–2) at discharge*		
AChA territory: spare or MT only versus full or other patterns of partial	7.24 (1.32 to 39.89)	0.023
Fair outcome (mRS 0–3) at discharge*		
AChA territory: spare or MT only versus full or other patterns of partial	5.30 (1.21 to 23.20)	0.027

*Adjustment for age, sex, baseline NIHSS, time interval between last known well and MRI, current smoking, intervention procedure, recanalisation status after intervention. mRS, modified Rankin Scale; MT, medial temporal lobe; NIHSS, National Institutes of Health Stroke Scale.

Contributors JLS and DSL designed the study. ML, JLS, QH, SS, NS, LKA, DK, BO, SS, RR, HA, RF and DSL participated in the data collection and extraction. ML did the statistical analysis with guidance from JLS and DSL. ML wrote the first draft of the report, and JLS and DSL did the major revision. All other authors commented on the draft and approved the final version. We thank Dr. Yen-Chu Huang for editing figure 1.

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Competing interests None.

Patient consent Exempt from consent.

Ethics approval This study was approved by the UCLA institutional review board.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Data sharing is covered by the institutional clinical research policies of UCLA Stroke Center.

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