Original Article

CT angiographic patterns predict carotid pseudo-occlusion in acute ischemic stroke

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Abstract

Background: Identifying carotid pseudo-occlusion (PO) from true occlusion (TO) has implications in determining the candidacy and feasibility of successful endovascular thrombectomy (EVT) in acute ischemic stroke (AIS). **Purpose:** We reviewed the computed tomography angiographic (CTA) patterns differentiating a PO from a TO and analyzed the rate of successful recanalization after EVT. **Materials and Methods:** Patients with AIS and proximal internal carotid artery (ICA) occlusion who underwent EVT from 2014 to 2021 were identified. The patterns of carotid occlusion in CTA were classified into beak, dome, and flat patterns and correlated with microcatheter digital subtraction angiography (DSA) as PO and TO. The rates of successful recanalization in PO and TO were analyzed. **Results:** Of the 24 patients, 16 (66%) had ICA PO and eight (33%) had TO in DSA. A beak pattern of the proximal ICA on CTA was significantly higher among the PO group patients (87.5% vs. 25%, $P = 0.005$), and a flat pattern was significantly higher among the TO group patients (50% vs. 12%, $P = 0.005$). A gradual contrast decline of the proximal ICA on CTA images was seen only in PO group patients (85.7% vs. 0%, $P = 0.05$). There was no significant difference in the rate of successful recanalization between PO and TO group patients (81.25% vs. 62.5%, $P = 0.362$). **Conclusion:** Beak pattern and gradual contrast decline at the proximal ICA occlusion site in CTA are suggestive of carotid PO. Identification of PO in CTA can help in planning intervention strategies and prognostication.

Keywords: Acute ischemic stroke, CT angiogram, pseudo-occlusion, true occlusion

Introduction

Carotid pseudo-occlusion (PO) refers to an artifactual occlusion of the proximal internal carotid artery (ICA) in computed tomography angiogram (CTA), which is originally patent, where a thrombus is present in the distal intracranial ICA or proximal middle cerebral artery (MCA). This occurs due to a stagnant column of unopacified blood proximal to the occlusion site and absence of distal contrast flow during the rapid image acquisition of the arterial phase of CTA.[1,2] Carotid PO is confirmed by microcatheter angiography distal to the PO site, showing a backfilling of the iodinated contrast material into the proximal extracranial ICA, indicating its actual patency.[1]

Endovascular thrombectomy (EVT) has become the standard of care in patients with a large artery occlusion in the window period after the major EVT trials.[3] Previous data showed that PO patients tend to fail first-pass recanalization, may require longer procedural times, and have a lower final recanalization rate after EVT compared to distal thrombi.[4] Better identification of PO has an impact on determining the candidacy of a successful EVT, and thus the functional outcome, and later the etiologic evaluation. Carotid occlusion site could be identified by certain imaging patterns, although PO is a poorly delineated entity. Our study aims to identify the CTA patterns differentiating a PO from a true occlusion (TO) and to analyze the rate of successful recanalization after EVT.

Materials and Methods

All patients above 18 years of age with acute ischemic stroke (AIS) and ICA occlusion, who underwent a CTA and digital subtraction angiography (DSA)/EVT within 24 h of onset of the stroke from 2014 to 2021 were identified from our prospectively maintained EVT database. Patients with AIS presenting with near occlusion of ICA, carotid dissection, and those who underwent magnetic resonance angiogram were excluded. The flowchart depicting the selection process of patients is shown in Figure 1. We collected the clinical and demographic data and stroke etiology as determined by the Trial of ORG 10172 in terms of Acute Stroke Treatment (TOAST) classification. The study was approved by the institutional ethics committee.

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Imaging analysis

All images were analyzed by a neurologist and a neuroradiologist blinded to the clinical details. CTA was performed using multidetector 256-section scanner (Brilliance iCT; Philips healthcare, the Netherlands), and we used an automated trigger technique for injection of contrast at 5 mL/s for a total of 50 mL, with 30 mL of normal saline as bolus chase. Scanning was performed from the aortic arch to the vertex. The 256-section scanner used a collimation of 128 × 0.625 mm, a pitch of 0.993, and a rotation time of 0.5 s to acquire the raw data, which was reconstructed at 0.9 mm thickness with 50% overlap for axial images. Thinner sections (0.9 mm at 50% overlap) were used to reconstruct axial images of the circle of Willis. Source images of the cervical carotid arteries were reconstructed as sagittal, coronal, and axial multiplanar images. Carotid occlusive imaging patterns were categorized into beak, dome, and flat patterns [Figures 2 and 3]. We also analyzed the gradual contrast decline and length of opacification of the proximal ICA in millimeters [Figure 4]. One out of total 24 patients, had underwent single phase CTA, which showed both beak pattern and gradient contrast decline and was found to have PO in DSA. Rest of the patients underwent multiphasic CTA, but the neck was not included in the second and third phase. The grading of posterior communicating (PCom) artery collaterals and Tan collateral grading were done.[5,6] The Guide catheter/microcatheter DSA injection images were reviewed, and the carotid occlusion site was categorized into PO and TO. The patterns of carotid occlusion in CTA were correlated with DSA images, and an assessment of how these patterns represent PO and TO was done.

The angiographic procedural factors (time from groin puncture to recanalization, first-pass recanalization, and degree of recanalization as assessed by modified thrombolysis in cerebral infarction [mTICI] score and 3-month modified Rankin scale [mRS] score) were analyzed. The rate of successful recanalization (mTICI grade 2b, 2c, and 3) and good functional outcome (mRS of 0–2) between PO and TO were analyzed.

Statistical analysis

Continuous variables were expressed as mean or median and categorical variables as percentages. Various demographic, clinical, CTA, and EVT outcome parameters were compared between the PO and TO groups using Fisher's exact test. A P value ≤ 0.05 was considered as statistically significant. All statistical analyses were performed using STATA/IC 14.1 (Texas, USA).

Results

For the 24 patients analyzed, the mean age at presentation was 61 ± 11 years, and majority of them were males (66%). Carotid PO was present in 16/24 (66%) patients, and eight (33%) patients had TO as determined by DSA. Majority of the patients with PO and TO had severe stroke at presentation; 62% had National Institutes of Health Stroke Scale (NIHSS) >15 in both groups. All patients with TO had large artery atherosclerosis (100% vs. 25%, $P = 0.001$), whereas cardioembolism was significantly higher in the PO group (43% vs. 0, $P = 0.01$). Table 1 shows the demographic and clinical characteristics of patients in the TO and PO group. Majority of the patients had a beak pattern of occlusion, that is, 16/24 (66.6%), whereas flat and dome patterns were observed in six (25%) and two (8.3%) patients, respectively. Beak pattern of occlusion was observed to be significantly higher among the PO group patients (87.5% vs. 25%, $P = 0.005$), whereas flat pattern was higher among the TO group patients (50% vs. 12%, $P = 0.005$). A gradual contrast decline of the proximal ICA on CTA images was seen only among the PO group patients (85.7% vs. 0%, $P = 0.05$). The difference in the mean

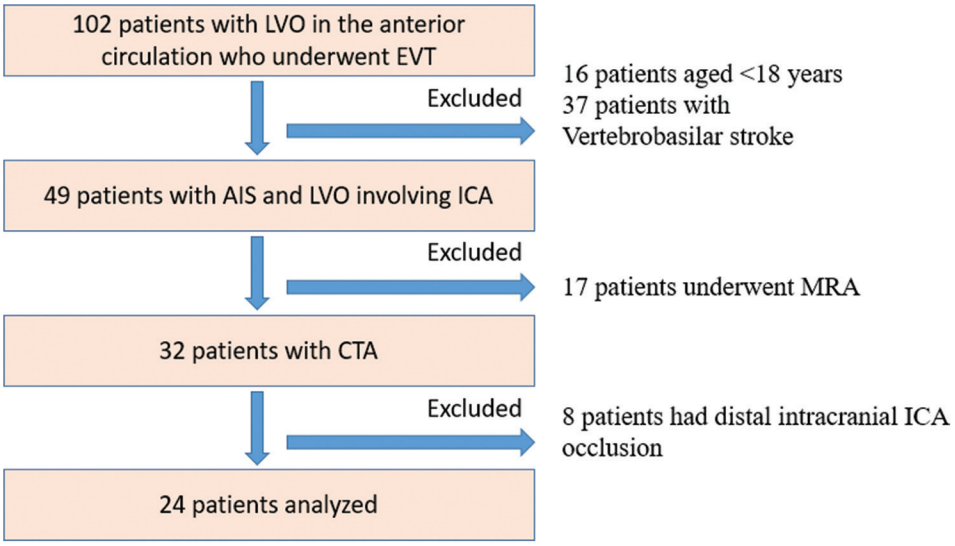

Figure 1: Flowchart showing patient recruitment for the study. AIS = acute ischemic stroke, CTA = computed tomography angiography, EVT = endovascular thrombectomy, ICA = internal carotid artery, LVO = large vessel occlusion, MRA = magnetic resonance angiography

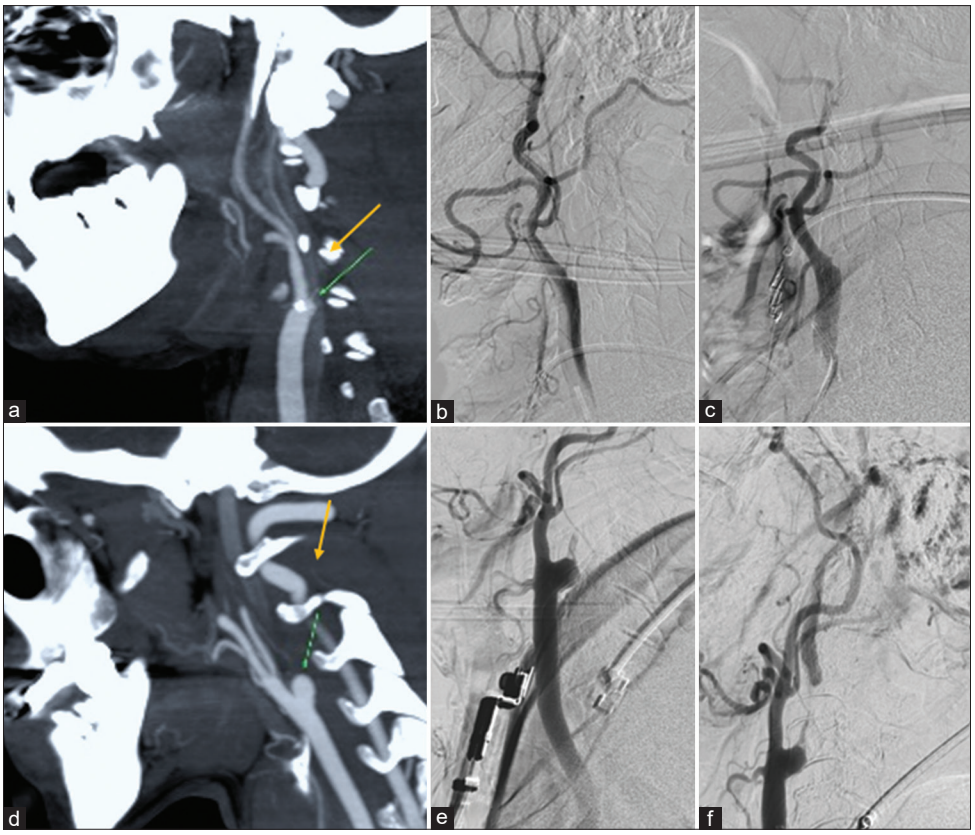

Figure 2: Imaging patterns of proximal ICA occlusion (a) flat shaped occlusion in CT angiography, (b) flat shaped occlusion in corresponding DSA (c) true occlusion demonstrated after microcatheter injection (d) dome shaped occlusion in CT angiography, (e) dome shaped occlusion in corresponding DSA (f) true occlusion demonstrated after microcatheter injection. ICA = internal carotid artery, CT = computed tomography, DSA = digital subtraction angiography

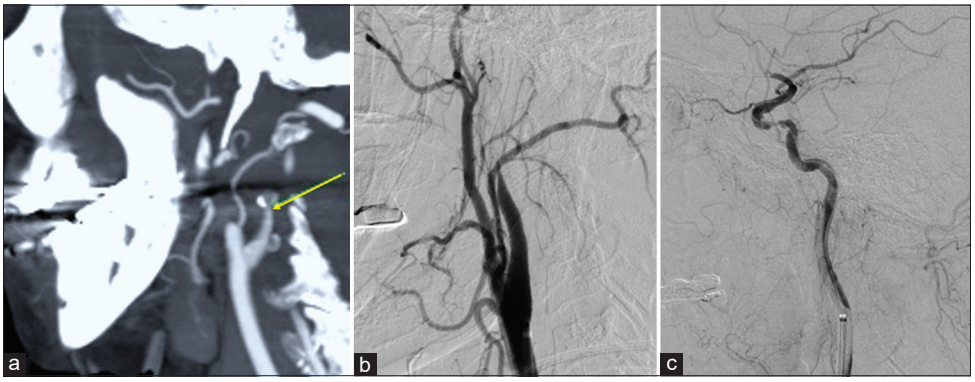

Figure 3: Imaging patterns of proximal ICA occlusion (a) flame shaped occlusion in CT angiography, (b) flame shaped occlusion in corresponding DSA (c) pseudo occlusion demonstrated after microcatheter injection. CT = computed tomography, DSA = digital subtraction angiography, ICA = internal carotid artery

length of opacification of proximal ICA between the PO and TO groups (14.35 ± 4.0 vs. 16.03 ± 4.8 mm, $P = 0.79$) was statistically not significant. About 75% of patients with TO had ophthalmic artery collaterals visualized and 62% had grade 3–5 PCom artery collaterals. A good recanalization (mTICI 2b–3) after EVT was achieved in 18/24 patients (81.25% in PO vs. 62.5% in TO, $P = 0.362$). The other procedural parameters (failed first pass recanalization, mean procedural duration) and mean temporal duration between CTA and DSA were not different between the two groups. The 3-month functional outcome (mRS) was also similar between the TO and PO groups (62.5% vs. 43.5%, $P = 0.667$).

Discussion

We observed that a beak pattern of carotid occlusion and a gradual contrast decline at the occlusion site were predictive of carotid PO and a flat pattern was suggestive of TO. The site of carotid occlusion has prognostic implications in AIS as the proximal thrombi are less amenable to intravenous thrombolysis

Table 1: Comparison of demographic, clinical, CTA and outcome parameters among PO and TO

Parameters	PO (*n*=16)	TO (*n*=8)	*P*
Age (years), mean ± SD	59±12	65±10	0.258
Male, n	12	6	0.681
Female, n	4	2	0.681
Admission NIHSS >15, *n* (%)	10 (62)	5 (62)	0.668
Imaging patterns, *n* (%)			
Beak pattern	14 (87.5)	2 (25)	0.005
Flat pattern	2 (12)	4 (50)	0.005
Dome pattern	0	2 (25)	0.005
Gradual contrast decline	12 (85.7)	0	0.05
Length of contrast opacification (mm), mean ± SD	14.35±4.0	16.03±4.8	0.79
Tan collateral Grade 2, *n* (%)	11 (68)	3 (31)	0.153
Tan collateral Grade 1, *n* (%)	5 (37)	5 (62)	0.153
Clot burden score ≥6, *n* (%)	2 (12.5)	0	0.435
Infraclinoid ICA involvement, n (%)	16 (100)	6 (65)	0.101
PCom collateral Grade 3-5, *n* (%)	5 (31)	5 (62)	0.153
Ophthalmic artery filling present, *n* (%)	6 (37)	6 (75)	0.09
Mean time interval between CTA and DSA (minutes), mean ± SD	48±13	61±33	0.243
Good recanalization (mTICI 2b, 2c, 3), n (%)	13 (81.25)	5 (62.5)	0.362
Failed first pass recanalization, n (%)	9 (56.25)	4 (50)	1.0
Mean procedure duration (minutes)	59	73	0.27
3-month mRS (0-2), n (%)	7 (43.5)	5 (62)	0.667
TOAST Etiology, n (%)			
Large vessel atherosclerotic disease	4 (25)	8 (100)	0.001
Cardioembolism	7 (43)	0	0.01

PO = pseudoocclusion, TO = true occlusion, SD = standard deviation, NIHSS = National Institutes of Health Stroke Scale, ICA = Internal carotid artery, PCom = Posterior communicating artery, CTA = Computed tomography angiography, DSA = Digital subtraction angiography, mTICI = modified thrombolysis in cerebral infarction, mRS = modified Rankin scale score, TOAST = Trial of ORG 10172 in Terms of the Acute Stroke Treatment

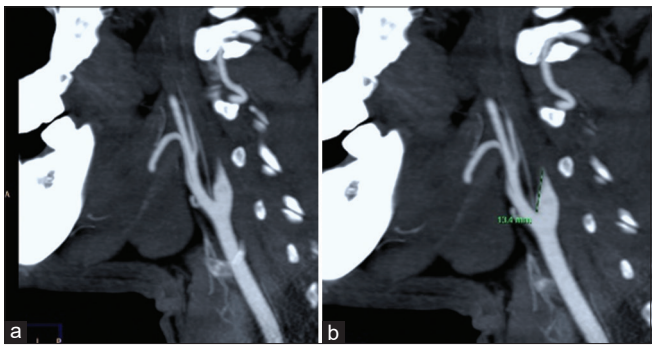

Figure 4: (a) Gradual contrast decline of proximal ICA, (b) Length of opacification of proximal ICA, here it is 13.4 mm. CT = computed tomography, DSA = digital subtraction angiography, ICA = internal carotid artery

and would suggest a probably difficult EVT procedure. PO is the artifactual proximal ICA occlusion, where a thrombus is in the distal ICA or MCA. Previous data showed poor recanalization and outcome after EVT in PO. This has been attributed to the thrombus extending even below the levels of a PCom artery, adversely affecting the Willisian collateral circulation and a propensity for thrombus extension, which negatively affects the outcome. We identified 16 patients (66%) with PO, which is higher than the previously reported prevalence of 11%–46%.[1,2,7] PO is usually diagnosed by superselective microcatheter DSA. There have been suggestions of certain imaging characteristics like rounded stump, streak, or spearhead pattern of occlusion and gradual contrast decline and the presence of calcifications successfully predicting the carotid occlusion site in CTA. Another study by Kim *et al*.[8] suggested that a beak pattern is more predictive of PO, which is attributed to the hemodynamic properties of blood vessel vascular shear stress. Our categorization into beak, flat, and dome patterns is easy for interpretation in the AIS setting. Our data suggests that a combination of beak pattern with gradual contrast decline indicates a carotid PO in CTA. Similarly, the total length of contrast opacification of proximal ICA, which was observed to be higher among PO group patients previously, was similar in the TO and PO patients in our study.[8]

Majority of our patients with TO had ophthalmic artery filling and good PCom artery collaterals, which supports the hypothesis of PO adversely affecting the collaterals. This could result in a smaller infarct growth and a relatively good functional outcome for the TO group, and previous studies had reported poor recanalization in PO patients (65% vs. 90.3%) owing to this poor recruitment of Willisian and leptomeningeal collaterals in PO. Conversely, in our cohort, PO patients had good recanalization of more than 80%, and we attribute this to the higher proportion of cardioembolic strokes in the PO group. Among those with occlusion due to cardioembolic source in the

PO group, six (85.7%) had good recanalization. About 50% of TO patients had failed first-pass recanalization and TO group patients had longer EVT procedure (73 vs. 59 min) duration, possibly attributed to the etiology of large artery atherosclerosis. TO patients had a better first-pass recanalization and lower EVT procedure duration, although all the patients with TO had large artery atherosclerosis. Even though previous studies found that PO patients failed first-pass recanalization, had lower final recanalization, and required longer procedural times and thus concluded PO to be a surrogate imaging marker of poor outcome,[1,4] we found that PO had a tendency for a shorter mean procedural time (59 vs. 73 min, $P = 0.27$) and a higher rate of good recanalization (mTICI 2b–3) than TO (81.25 vs. 62.5%, $P = 0.362$).

The strength of the study is that all our patients had a 3-month follow-up. The limitations of our study are its retrospective design, small sample size, and single-center data.

In conclusion, beak pattern and gradual contrast decline at the proximal ICA occlusion site in CTA are suggestive of carotid PO. Identification of PO in CTA can help in planning intervention strategies and prognostication.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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