

Differentiating pseudo-occlusion from true occlusion of proximal internal carotid artery in acute ischemic stroke on CT angiography

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ABSTRACT

Objective: A lack of visualization of the proximal internal carotid artery (ICA) on computed tomography angiography (CTA) in acute ischemic stroke may be caused by an atherosclerotic occlusion or a pseudo-occlusion by a massive thrombus in the ICA. Pseudo-occlusion of the proximal ICA is caused by stagnant flow from a distal ICA occlusion. The purpose of this study aimed to use imaging findings of CTA to differentiate pseudo-occlusions from true occlusions of the proximal ICA.

Patients and methods: All eligible patients undergoing endovascular treatment after CTA from January 2013 to March 2018 were respectively reviewed. Patients with < 2 cm of ICA on CTA images were enrolled in this study. CTA images were classified as having a beak, dome, or flat pattern.

Results: Our sample included a total of 66 eligible patients (true occlusion: 31, pseudo-occlusion: 35). The total length of opacification of the proximal ICA in the pseudo-occlusion group was significantly higher compared to that in the true occlusion group (13.9 ± 4.0 vs. 6.1 ± 4.8 , $p < 0.001$). A beak pattern of the proximal ICA on CTA images was significantly higher in the pseudo-occlusion group (82.9% vs. 16.1%, $p < 0.001$), but a flat pattern was significantly higher in the true occlusion group (58.1% vs. 0%, $p < 0.001$). Gradual contrast decline of the proximal ICA on CTA images only appeared in the pseudo-occlusion group (51.4%, $p < 0.001$).

Conclusions: On CTA, imaging patterns of the proximal ICA can be differentiated between true occlusions and pseudo-occlusions.

1. Introduction

Computed tomographic angiography (CTA) has been widely used to diagnose acute ischemic stroke, including cervical internal carotid artery (ICA) occlusion [1–4]. In occlusion strokes, reperfusion time is essential when predicting outcomes [5,6]. In addition, different occlusion sites can result in different clinical manifestations and prognoses of various acute ICA occlusions [7]. But difficulty in discriminating a pseudo-occlusion from a true occlusion can hinder determination of the optimal endovascular treatment (EVT) [3,7]. For this reason, effective discrimination between true occlusions and pseudo-occlusions may result in better therapeutic outcomes for patients with acute ischemic stroke concomitant with ICA occlusion.

Cervical ICA pseudo-occlusion occurs when a thrombosis in the intracranial ICA or proximal middle cerebral artery (MCA) makes a flow-related artifact leading to the misdiagnosis of a true ICA occlusion,

when in actuality the extracranial ICA is patent [2,4,5,7]. This finding happens because rapid image acquisition outruns the absent contrast flow, forming a stagnant column. The presence of a pseudo-occlusion can be confirmed by performing microcatheter angiography distal to the pseudo-occlusion site, which will show backfilling of contrast in the proximal ICA, proving its patency [2].

To determine an occlusion site, interpretation of CTA image findings can be useful and has been described in previous studies. For example, certain imaging characteristics, such as gradual contrast decay, carotid occlusive patterns, and presence of calcification can suggest an occlusion site [7].

The aim of this study was to make identifying occlusion sites on CTA more accurate to make determination of endovascular treatment more straightforward in order to achieve better outcomes in patients with acute ischemic stroke. We distinguished proximal ICA image findings on CTA of patients with an ICA occlusion according to 'beak', 'dome',

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and 'gradual contrast decline' patterns. Then we retrospectively evaluated how these patterns represented true occlusions or pseudo-occlusions of the ICA.

2. Materials and methods

The study protocol was approved by our institutional review board. Informed consent was waived from relatives of the deceased.

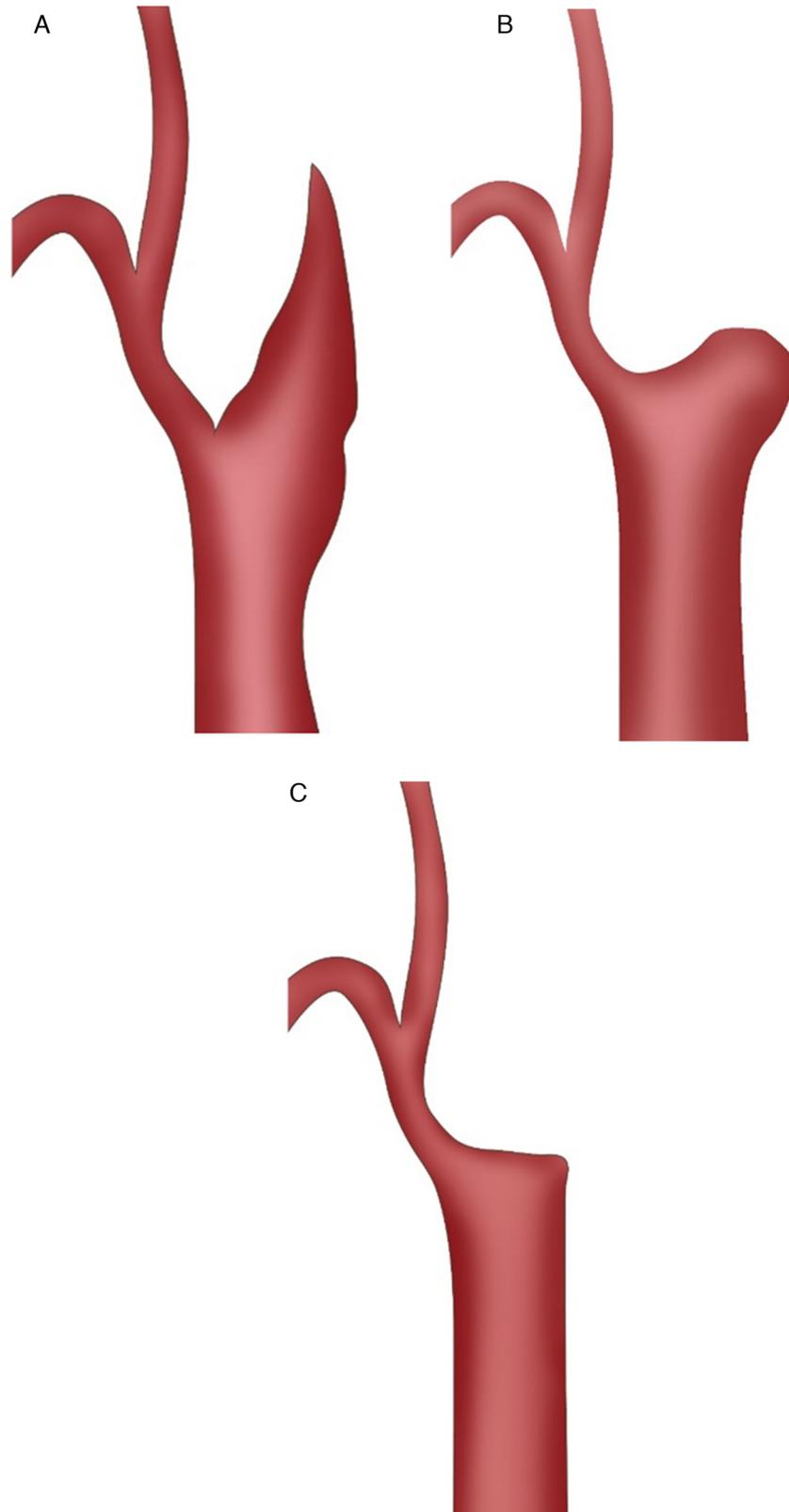


Fig. 1. Schematic figure of 3 imaging patterns of proximal internal carotid artery occlusion on CT angiography. (A) Beak, (B) Dome, (C) Flat.

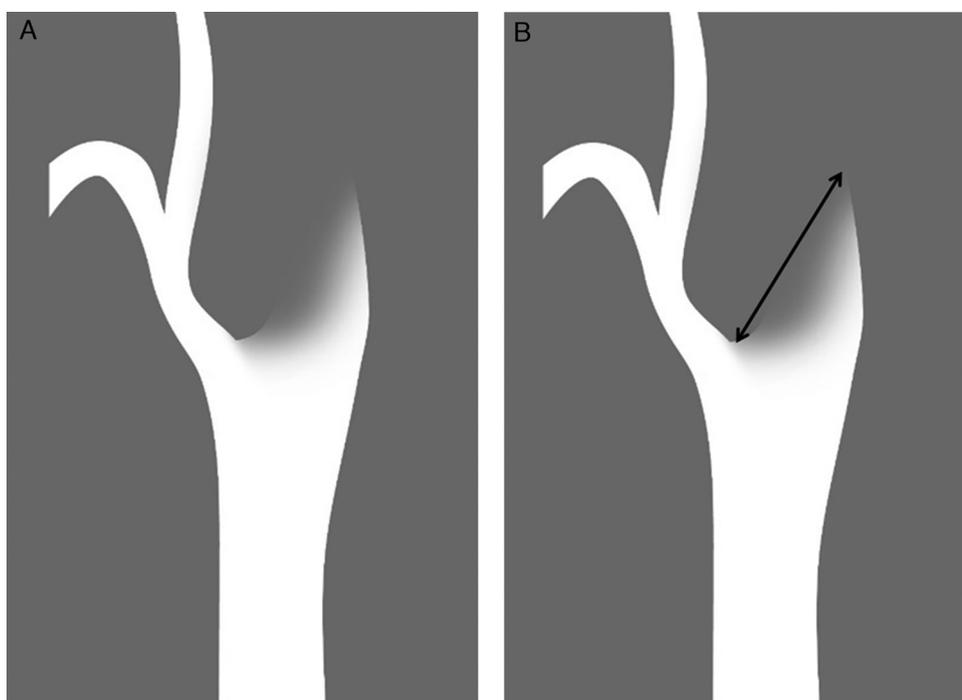


Fig. 2. Schematic figure of gradual contrast decline and total length of contrast filling of proximal ICA occlusion on CTA angiography. (A) Gradual contrast decline: decreased contrast filling of distal margin of contrast filled proximal ICA. (B) Total length between carotid bifurcation and distal margin of contrast filled proximal ICA.

Table 1
Demographic data and imaging findings of proximal ICA occlusion on CTA.

	True (n = 31)	Pseudo (n = 35)	p
Age, years	74.2 ± 9.8	73.6 ± 11.2	0.793
Male, n (%)	26 (83.9)	27 (77.1)	0.702
Right, n (%)	17 (54.8)	14 (40.0)	0.344
Imaging findings			
Beak, n (%)	5 (16.1%)	29 (82.9%)	< 0.001
Dome, n (%)	8 (25.8%)	6 (17.1%)	0.578
Flat, n (%)	18 (58.1%)	0 (0%)	< 0.001
Gradual contrast decline, n (%)	0 (0.0%)	18 (51.4%)	< 0.001
Total length, mm	6.1 ± 4.8	13.9 ± 4.0	< 0.001

2.1. Patients

This was a retrospective analysis of single center data on endovascular treatment (EVT) in patients with acute ischemic stroke from January 2013 to March 2018. During this period, 607 patients underwent EVT for recanalization of vessel occlusion of the anterior circulation. Our criteria for EVT were as follows: (1) age \geq 18 years; (2) initial National Institutes of Health Stroke Scale (NIHSS) score \geq 4; (3) no evidence of intracerebral hemorrhage detected on non-enhanced CT; (4) obvious major vessel occlusion of the anterior circulation on CT angiography (CTA); (5) infarct core volume less than one-third of the MCA territory on the source image of CTA. Our stroke protocol was as follows: (1) initial non-enhanced CT for evaluation of hemorrhage; (2) CTA with/without perfusion CT for evaluation of vessel occlusion. Of 607 patients, 107 with extracranial internal carotid artery (ICA) occlusion on CT angiography were enrolled in this study.

2.2. CT acquisition

Initial non-enhanced CT (SOMATOM Sensation 16 or Definition Flash; Siemens, Erlangen, Germany) with a slice thickness of \leq 5 mm were obtained for all patients. Patients in our sample had a non-contrast CT, followed by a CTA, which was performed by scanning from the cerebral vertex to the aortic arch with 0.7-mm section thickness slices. Nonionic contrast media (80–120 ml) was administered into the antecubital vein at 3–5 ml/s, and the CTA source images were post-

processed and reformatted to create coronal, sagittal, and axial multiplanar images.

2.3. Image analysis

We divided the 2 groups based on the angiographic findings of the EVT. Atherosclerotic true ICA occlusion was the complete occlusion by plaque or calcification with no visualization of distal contrast filling above the occlusion segment. Pseudo-occlusion was no contrast filling due to distal ICA or large M1 thrombotic occlusion and no plaque or calcification of the carotid orifice. We excluded patients with contrast filling of the proximal ICA above 2 cm because of the bias of pseudo-occlusion.

We divided 3 patterns of proximal ICA occlusion on CTA (Fig. 1). A flat pattern was defined as no visualization of proximal ICA contrast filling. A dome pattern was defined as a round shape of the distal portion of the proximal ICA. A beak pattern was defined as a rapid tapering of the proximal ICA. Also, we analyzed the gradual contrast decline of the proximal ICA and the total length of contrast filling of the proximal ICA (Fig. 2).

Two neuroradiologists with 20 and 11 years of experience, respectively, who were blinded to the clinical information of each patient and the purpose of this study, determined the result of the image analysis by consensus.

2.4. Statistical analysis

The analysis was performed by using SPSS 24.0 (IBM SPSS, Armonk, NY) and MedCalc (MEDCALC, Ostend, Belgium). Continuous values are expressed as medians and/or ranges and categorical data as counts and percentages. Continuous and categorical variables were compared among these groups using the Mann-Whitney test and Fisher's exact test, respectively. Statistical significance was defined as $p < 0.05$. We described receiver operating characteristic (ROC) curve analysis and the area under the curve (AUC) for evaluation of diagnostic value of CTA imaging findings in patients with proximal ICA occlusion.

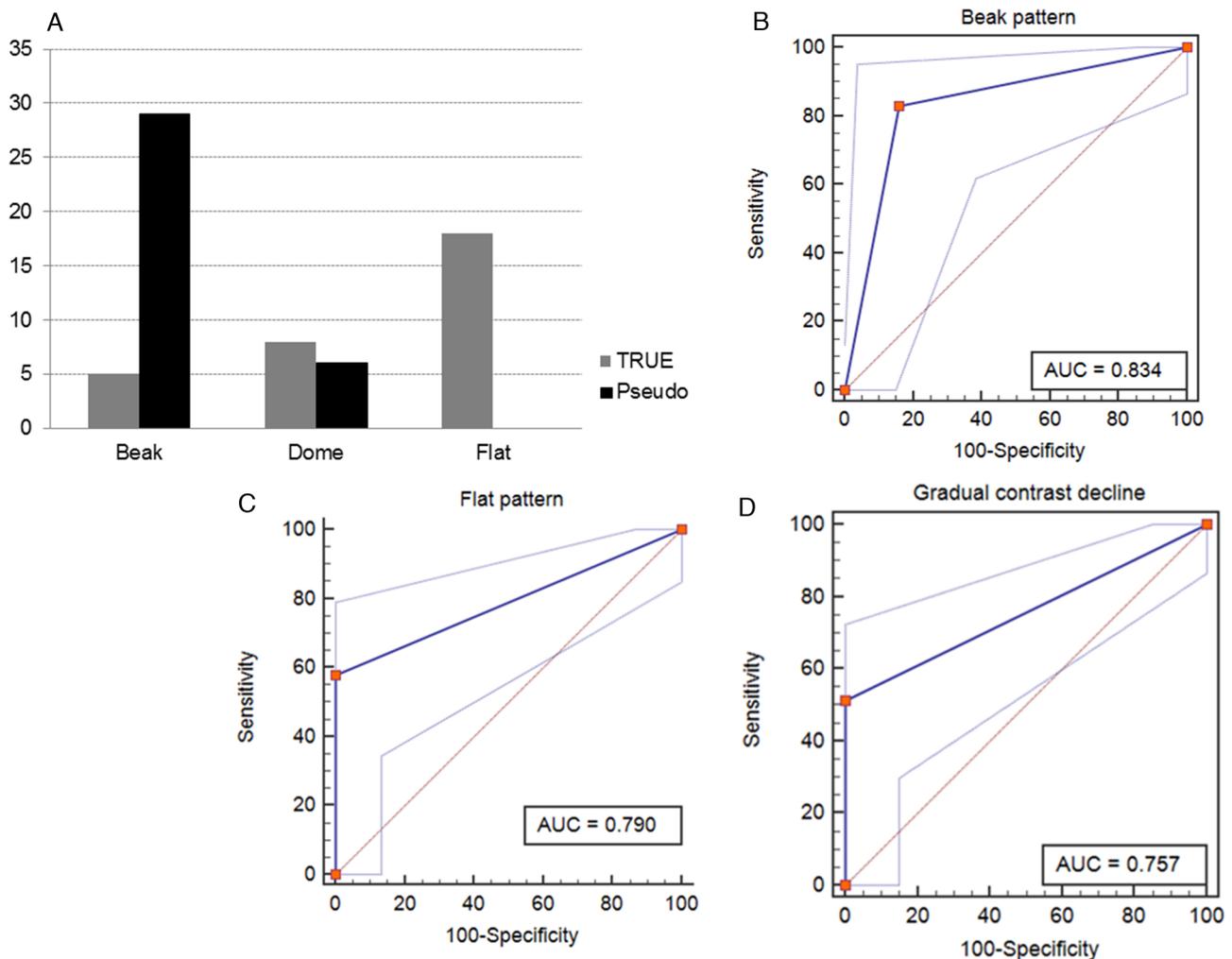


Fig. 3. The frequency of imaging pattern of proximal ICA occlusion on CTA and ROC curve using each pattern on CTA. (A) The frequency of 3 patterns between true and pseudo-occlusion. (B) ROC curves of beak pattern in patients with pseudo-occlusion. (C) ROC curves of beak pattern and gradual contrast decline in patients with pseudo-occlusion. (D) ROC curves of flat pattern in patterns with true occlusion.

3. Results

Of 107 patients with extracranial ICA occlusion on CT angiography, 41 were excluded because contrast filling of the proximal ICA was above 2 cm. Thirty-one patients had atherosclerotic ICA occlusion, and 35 had pseudo-occlusion by contrast stagnation of the proximal ICA due to a massive thrombus of the proximal ICA, distal ICA, or large M1 on cerebral angiography.

The demographic data and imaging results of proximal ICA occlusion on CTA are shown in Table 1. The beak pattern of the proximal ICA on CTA images was significantly higher in the pseudo-occlusion group (82.9% vs. 16.1%, $p < 0.001$), but the flat pattern was significantly higher in the true occlusion group (58.1% vs. 0%, $p < 0.001$) (Figs. 3 and 4). Gradual contrast decline of the proximal ICA on CTA images only appeared in the pseudo-occlusion group (51.4%, $p < 0.000$). The gradual contrast decline was not shown in patients with a true occlusion of the proximal ICA. The diagnostic value of each imaging finding using ROC analysis is shown in Table 2. The AUC of the beak pattern for diagnosis of a pseudo-occlusion of the proximal ICA was the highest at 0.834. The AUC of the flat pattern for diagnosis of a true occlusion was the highest at 0.790. The total length of contrast filling of the proximal ICA in the pseudo-occlusion group was significantly higher compared to that in the true occlusion group (13.9 ± 4.0 vs. 6.1 ± 4.8 , $p < 0.001$).

4. Discussion

This study demonstrated that the CTA finding of a true proximal ICA occlusion is a flat pattern, and the findings of a proximal ICA pseudo-occlusion are a beak pattern and gradual contrast decline.

Vessel imaging is mandatory to define the site of occlusion and select patients for EVT. A proximal occlusion should prompt consideration of endovascular recanalization. Diagnosis of proximal ICA occlusion is made by CT angiography as a protocol for acute ischemic stroke. Especially, it is necessary to distinguish for EVT between a true-occlusion by atherosclerosis and a pseudo-occlusion by a distal or proximal occlusion. EVT for a true occlusion is sometimes technically challenging and time-consuming with respect to the procedure time [8,9]. Previous research has reported the prevalence of pseudo-occlusions to be 6%–14% [2,10,11]. Some papers have reported that a pseudo-occlusion can be misleadingly interpreted as a true occlusion on CTA [7,11]. The mechanism of a pseudo-occlusion is sluggish or absent contrast flow caused by a distal occlusion. The characteristic imaging findings of a pseudo-occlusion on CTA are a beak-like tapering of the proximal ICA [7,12] and good contrast filling of the carotid bulb followed by gradual contrast decline in the ICA [13]. Especially, contrast filling and gradual contrast decline of a long segment proximal ICA has a relatively high sensitivity for detection of distal ICA occlusion [7]. So, our study excluded patients with contrast filling of the proximal ICA above 2 cm because of bias of pseudo-occlusion.

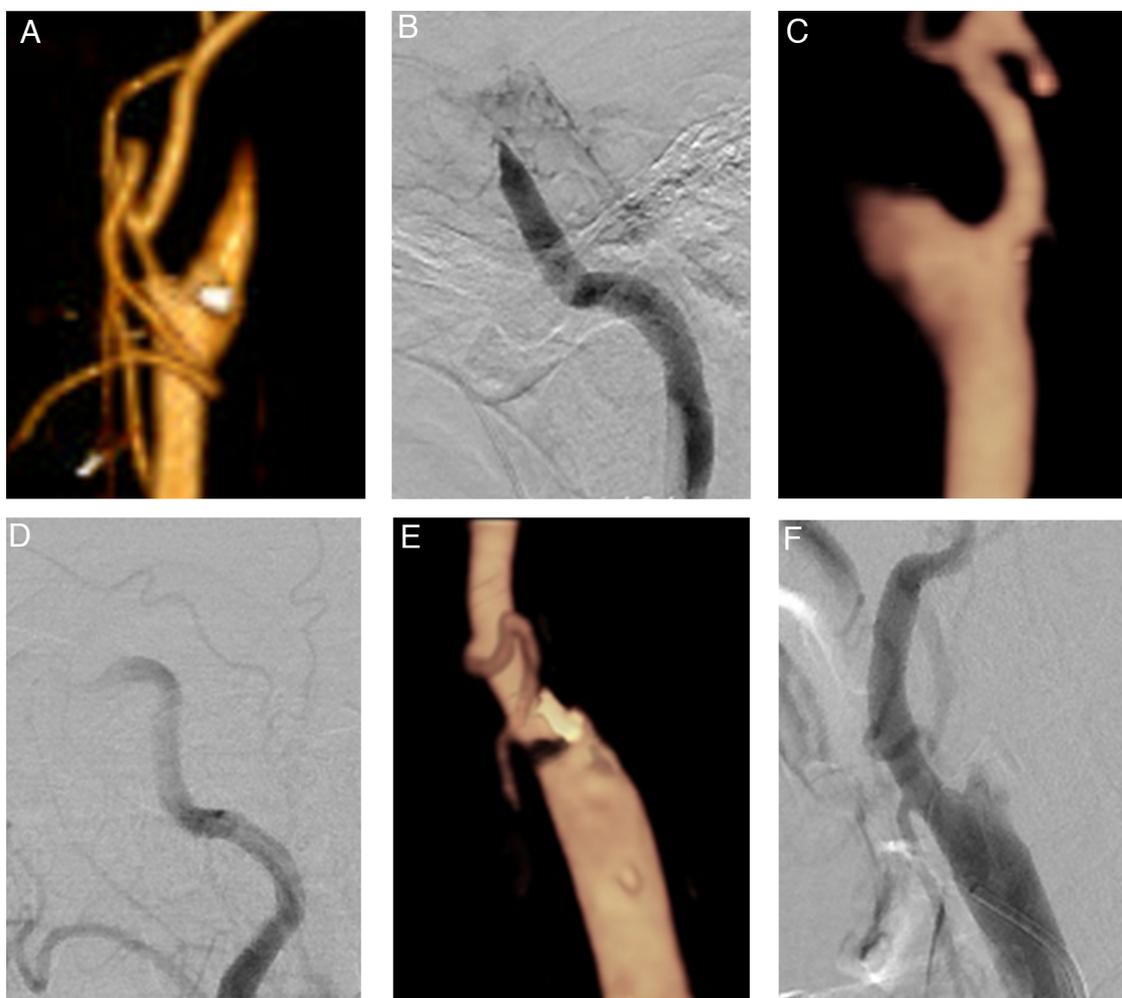


Fig. 4. Examples of three patterns of proximal ICA occlusion on CT angiography.

A and B. CTA of a 57-year old man with right hemiplegia shows the beak pattern of proximal ICA occlusion on CTA (A). Cerebral angiography shows the complete thrombotic occlusion of petrous ICA (B).

C and D. CTA of a 54-year old man with left hemiplegia shows the dome pattern of proximal ICA occlusion (C). Cerebral angiography shows the thrombotic occlusion of ICA terminus (D).

E and F. CTA of a 73-year old man with left hemiplegia shows the flat pattern of proximal ICA occlusion (E). Cerebral angiography shows the complete occlusion with plaque (F). He underwent the carotid stent and endovascular treatment about MCA occlusion.

Table 2

Area under the curve (AUC) of receiver operating characteristic (ROC) curve analysis of each imaging finding.

	AUC (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)
Beak pattern ^a	0.834 (0.722–0.914)	82.9 (66.4–93.4)	83.9 (66.3–94.5)
Gradual contrast decline ^a	0.757 (0.636–0.854)	51.43 (34.0–68.6)	100 (88.8–100)
Flat pattern ^b	0.790 (0.673–0.881)	58.6 (39.1–75.5)	100 (90.0–100)

In our study, we tried to distinguish CTA images of cervical ICA occlusion using image finding patterns such as beak, flat, or dome. A beak pattern of the enhanced proximal ICA that is tapered and sharp at the end had a sensitivity of 82.9% and specificity of 83.9%. This result was similar to previous reports [7,13]. The velocity of blood is faster when it is in the center of a vessel because of vascular wall shear stress. So, we can see that enhanced blood is filled first in the vascular center and makes a sharp shape in the ICA like a beak. Also, in our study, gradual contrast decline only appeared in pseudo-occlusions. The specificity was 100%, although the sensitivity was relatively low at 51.43%. A beak pattern and gradual contrast decline of the proximal ICA on CTA images were significantly higher in the pseudo-occlusion group.

A flat pattern, no contrast filling in the proximal ICA, had 100%

specificity, though a relatively low sensitivity of 58.6%. That means contrast enhanced blood had no place to go when passing the ICA, which helps reach the conclusion that the proximal ICA, near the bifurcation of the common carotid artery, is occluded. Although a flat pattern had a relatively low sensitivity for detection of a true occlusion, it was significantly higher in the true occlusion group. Our sensitivity was relatively low compared with previous studies [7,13]. We included a dome pattern for analysis of the proximal ICA. The dome pattern showed a similar prevalence between the 2 groups. We found a dome pattern in patients with a massive thrombus in the proximal ICA.

The limitations in our study are related to its retrospective design and small sample size. Patients who only underwent CTA and EVT were included in this study, and we excluded patients with contrast filling of the proximal ICA above 2 cm because of bias of pseudo-occlusion. And

the analysis was performed with single center data. That could represent a potential source of selection bias. However, the criteria for EVT and the stroke protocol at our institution are in line with current standards, and our sample size is larger than in some previous studies. We hope further studies with a prospective or multicenter design can confirm our findings.

5. Conclusion

Imaging patterns of the proximal ICA on CTA can differentiate between true occlusions and pseudo-occlusions. Imaging findings of true occlusions by atherosclerosis of the proximal ICA have a flat pattern, and pseudo-occlusions of the proximal ICA by a thrombus of the distal ICA have a beak pattern and gradual contrast decline. We expect that our research can help radiologists and neurologists make decisions regarding their therapeutic approach and predict outcomes of patients with cervical ICA occlusions.

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Ethical approval

Our institutional review board approved this retrospective study.

Declaration of Competing Interest

None.

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