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Use of 4D Computer Tomographic Angiography to Accurately Identify Distal Internal Carotid Artery Occlusions and Pseudo-Occlusions: Technical Note

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Abstract

Background and Purpose—Traditional methods of computed tomographic angiography (CTA) can be unreliable in detecting carotid artery pseudo-occlusions or in accurately locating the site of carotid artery occlusion. With these methods, lack of adequate distal runoff due to pseudo-occlusion or intracranial occlusion can result in the inaccurate diagnoses of complete occlusion or cervical carotid occlusion, respectively. The site of carotid occlusion has important therapeutic and interventional considerations. We present several cases in which 4D CTA was utilized to accurately and noninvasively diagnose carotid pseudo-occlusion and intracranial internal carotid artery (ICA) occlusion.

Methods—We identified five patients who presented to our institute with ischemic stroke symptoms and evaluated images from traditional CTA protocols and 4D CTA protocols in each of these patients, comparing diagnoses rendered by each imaging technique.

Results—In two patients, traditional CTA suggested the presence of complete ICA occlusion. However, 4D CTA demonstrated pseudo-occlusion. Similarly, in three patients, traditional CTA demonstrated cervical ICA occlusion, whereas the 4D CTA demonstrated intracranial ICA occlusion.

Conclusion—4D CTA may be a more effective noninvasive imaging technique than traditional CTA to detect intracranial carotid artery occlusions and carotid artery pseudo-occlusions. Accurate, rapid, and noninvasive diagnosis of carotid artery lesions may help tailor and expedite endovascular intervention.

Keywords

carotid terminus occlusion; computed tomographic angiography; imaging; internal carotid artery; pseudo-occlusion

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Table 1. Description of five patients in whom 4D CTA accurately identified the pathologic site, which was misdiagnosed with the use of traditional CTA imaging

Patient	Age	Sex	Traditional CTA*	4D CTA	DSA
1	64	M	Midcervical complete left ICA occlusion	Left ICA pseudo-occlusion	Left ICA dissection
2	54	F	Distal cervical complete right ICA occlusion	Right ICA pseudo-occlusion	Right ICA dissection
3	67	M	Distal cervical right ICA occlusion	Right ICA terminus occlusion	Right ICA terminus occlusion
4[a]	72	F	Proximal left ICA occlusion	Left ICA terminus occlusion	Left ICA terminus occlusion
5[b]	75	M	Middle right ICA occlusion	Right ICA terminus occlusion	Right ICA terminus occlusion

Abbreviations: 4D, four-dimensional; CTA, computed tomographic angiography; DSA, digital subtraction angiography; ICA, internal carotid artery.

*Reflects the interpretation rendered by staff neuroradiologist (blinded to 4D CTA images).

[a]Patient depicted in Figure 1.

[b]Patient depicted in Figure 2.

INTRODUCTION

The severity of extracranial carotid artery stenosis has been shown to affect prognosis and morbidity in the setting of acute ischemic stroke. Carotid artery occlusion is at one end of the spectrum and bodes a particularly dismal prognosis given its resistance to noninvasive treatment strategies. Differentiating complete carotid occlusion from pseudo-occlusion has been challenging with noninvasive methods [1].

Siddiqui *et al*. observed the presence of a "cervical pseudo-dissection phenomenon" observed in patients with intracranial ICA occlusions [2]. These authors describe the identification of intracranial occlusion via cerebral angiography and subsequent resolution of the pseudo-dissection appearance following recanalization of the distal occlusion. They hypothesize that this phenomenon occurs due to the lack of distal runoff of contrast material and the stagnant column of blood caused by this distal occlusion. In our clinical experience, we have noticed intracranial internal carotid artery (ICA) occlusions and pseudo-occlusions to have an appearance similar to that of cervical ICA occlusion on traditional computed tomographic angiography (CTA) of the head and neck. We posit that this observation is due to a combination of the aforementioned hemodynamic factors and the fact that CTA images are typically obtained at the peak arterial phase. Here, we report the use of time-resolved whole-head CTA (4D CTA) to noninvasively and accurately identify patients with distal ICA occlusions and pseudo-occlusions. Rapid identification of these pathologic conditions during preintervention work-up may help direct endovascular intervention and eliminate delays in recanalization.

METHODS

Patients presenting to our institute with symptoms of stroke routinely undergo imaging evaluation consisting of head noncontrast computed tomography (CT), CT perfusion, and CTA (traditional and 4D) of the head and neck (i.e., CT stroke study). These images are acquired according to the Neuro ONE protocol [3]. Postprocessing and subsequent analysis of perfusion maps are performed on a Vitrea workstation (Vital Images and Toshiba) by the neuroendovascular team prior to intervention.

We identified five patients who presented to our institute with stroke symptoms between July 2014 and June 2015 and were ultimately found to have intracranial ICA occlusion and/or ICA pseudo-occlusion. We evaluated each of these patients using two imaging strategies—traditional (3D) CTA and postprocessed 4D CTA. Traditional CTA postprocessing routinely was evaluated by a staff neuroradiologist who was blinded to the 4D postprocessing imaging sets. We then compared these noninvasive imaging findings to those found on the gold standard, traditional cerebral digital subtraction angiography (DSA).

To evaluate the difference in radiation dose between 4D CTA and traditional CTA, we measured the dose length product (DLP) to the body and head in 10 consecutive patients undergoing each test. There were no changes in imaging protocols between these 20 patients and those included in our study.

The study was approved by the University at Buffalo Health Sciences Institutional Review Board (project no. 707604-1).

RESULTS

Details for the five patients in whom 4D CTA aided in accurate identification of the pathologic site are provided in Table 1.

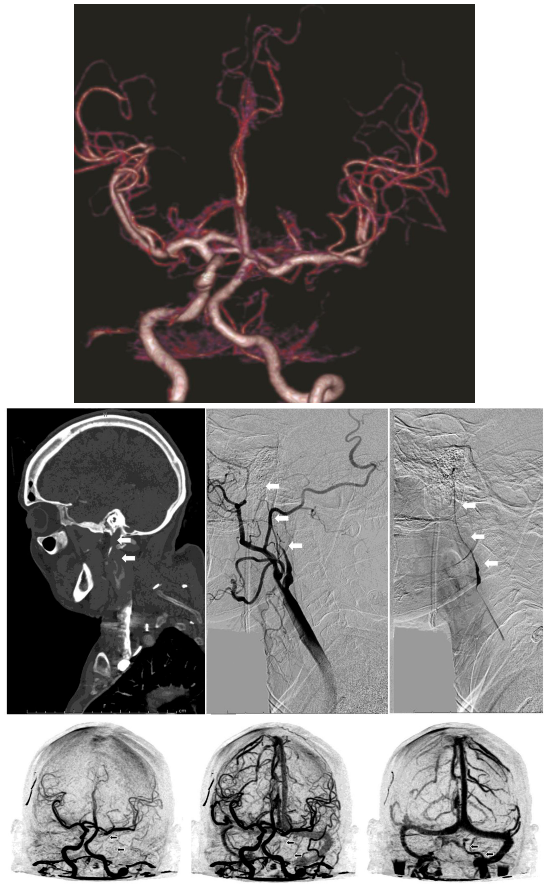

Figure 1. (Patient 4 in Table 1). [color (top)] 3D reconstruction of traditional CTA image acquisition demonstrating no filling of the visible segments of the left ICA (from the distal cervical segment to the ICA terminus). [middle (left)] Sagittal reformat of traditional CTA demonstrating no evidence of left ICA filling from the midcervical segment through its entrance into the skull base (arrows). This suggests proximal ICA occlusion. [middle (center)] Lateral view of early arterial phase DSA of the cervical left ICA. Filling of the distal ICA (arrows) is not seen in this early arterial phase due to blood flow stagnation caused by an ICA terminus occlusion. [middle (right)] Lateral view of late venous phase DSA of the cervical left ICA. Weak filling is seen in the distal cervical ICA (arrows) and as the ICA enters the skull base. This demonstrates that the site of occlusion is not in the proximal ICA as suggested by the CTA, but rather in the intracranial ICA. [bottom (left)] Anteroposterior (AP) view of early arterial phase 4D CTA. This image roughly corresponds to the time of image acquisition of traditional CTA. Consequently, this image resembles that of the 3D CTA reconstruction (top, color). No filling of the left ICA is noted in the distal cervical and intracranial segments (arrows). [Bottom (center)] AP views of early venous phase 4D CTA. Again, the distal cervical and intracranial ICA is not seen (arrows). [Bottom (right)] AP views of late venous phase 4D CTA. the left Ica is seen filling anterogradely in delayed fashion (arrow). However, there is no filling at the ICA terminus, suggesting that this is the site of occlusion. the severely delayed filling is likely due to the lack of distal runoff, which creates a stagnant column of blood. This was confirmed using DSA (D, image on the right in the previous composite).

In two patients, traditional CTA suggested the presence of complete cervical ICA occlusion, whereas 4D CTA demonstrated the presence of pseudo-occlusions that were ultimately found to be dissections on cerebral angiography. Similarly, CTA suggested the presence of complete cervical ICA occlusion in three other patients in whom 4D CTA demonstrated intracranial ICA terminus occlusions that were confirmed with cerebral angiography (Figures 1 and 2).

The mean DLP to the head was 4807.0 mGy in the patients undergoing 4D CTA and 1211.9 mGy in those undergoing traditional CTA ($P < 0.0001$). Similarly, the mean DLP to the body was 619.8 mGy in those undergoing 4D CTA and 346.8 mGy in those undergoing traditional CTA ($P < 0.0001$).

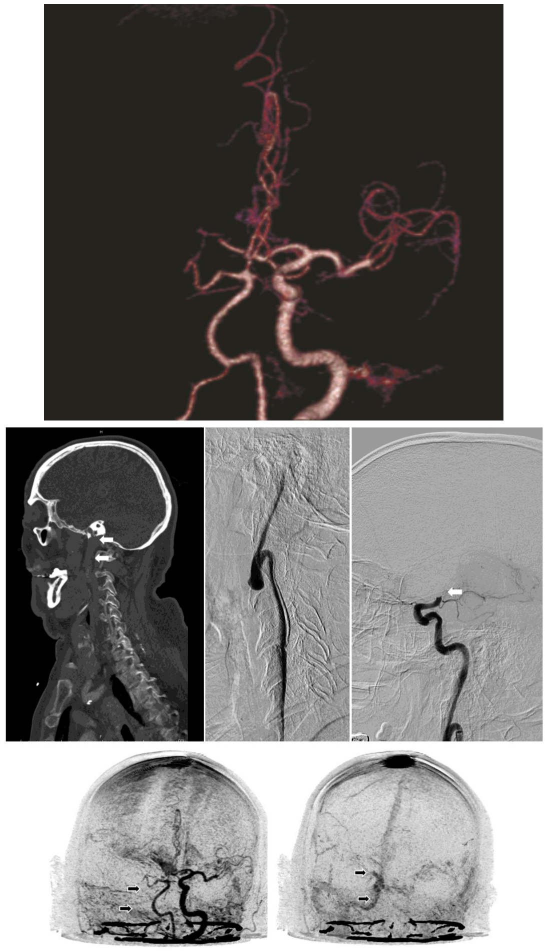

Figure 2. (Patient 5 in Table 1). [top (color)] 3D reconstruction of traditional CTA image demonstrating no filling of the right ICA or its branch vessels. [middle (left)] Sagittal reformat of traditional CTA image demonstrating no filling of the distal right ICA (arrows). Faint contrast filling is noted proximally, which appears to stop at the midcervical ICA. [middle (center)] Lateral view of midarterial phase Dsa of the right cervical Ica. the "pseudo-dissection phenomenon" described by Siddiq et al. [2] can be seen as decreased caliber of both the proximal and distal Ica. [D (right)] Lateral view of late arterial phase DSA demonstrating a right carotid terminus occlusion (arrow). There is no blood flow distal to the occlusion, representing complete occlusion (TICI 0). [bottom (left)] Anteroposterior (Ap) view of peak arterial phase 4D CTA. This roughly corresponds to the time of image acquisition of traditional CTA (a, color). There is no filling of the right ICA (arrows). [Bottom (right)] AP views of very late venous phase 4D CTA. Contrast material can be seen within the petrous, cavernous, and supraclinoid right ICA (arrows). No contrast is seen distal to the carotid terminus, which was confirmed with DSA to be the side of occlusion (middle, image on the right in the previous composite).

DISCUSSION

Identification of carotid artery pseudo-occlusion and its differentiation from complete occlusion are critical in the work-up of patients presenting with acute ischemic stroke. This significance was exemplified by the results of the Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in the Netherlands [4], in which the greatest interventional treatment benefit and harm from medical therapy alone were derived in patients with cervical carotid occlusions. Cervical occlusions that are calcific and atherosclerotic in origin may require stenting for distal access. Making this determination upon presentation is critical so that optimal antiplatelet and medical therapy may be initiated at that time.

To date, noninvasive imaging techniques have been unreliable in their ability to detect carotid artery pseudo-occlusion. Furst *et al*. [5] demonstrated that 36% of carotid pseudo-occlusions were misdiagnosed as complete occlusions using 2D time-of-flight (TOF) magnetic resonance angiography, whereas 53% were misdiagnosed using 3D TOF. They further noted that carotid Doppler imaging was only slightly more accurate: 30% of pseudo-occlusions were misdiagnosed as complete occlusions.

Siddiq *et al*. [2] reported the presence of a "pseudo-dissection phenomenon" associated with intracranial ICA occlusion. These authors describe the traditional flame-shaped appearance resembling dissection in seven patients who were ultimately found to have intracranial ICA occlusions. They hypothesize that this appearance is caused by a complete cessation of distal contrast runoff (due to the occlusion), which results in a stagnant column of blood.

The principle of lack of distal runoff causing a stagnant column of blood can be applied for noninvasive imaging. Traditional postprocessing of CTA images occurs using images acquired during the peak arterial phase. With intracranial occlusions or pseudo-occlusions, distal contrast runoff is significantly impeded but not entirely absent; there is anterograde runoff from petrous and cavernous branches but compared to normal outflow, this is substantially restricted. Therefore, if image acquisition is obtained early, a column of stagnant (in the setting of distal occlusion) or near-stagnant (in the setting of pseudo-occlusion) contrast material may suggest complete proximal occlusion of the vessel. Marquering *et al*. [6] recently described six patients in whom traditional CTA demonstrated extracranial ICA occlusion, which was proven to be inaccurate on evaluation with angiography. In four of these cases, patients were found to have carotid terminus occlusions; in the remaining two patients, severe stenosis was noted.

Delay in endovascular intervention for large vessel occlusions has been shown to be a predictor of poor functional outcome [7]. Similarly, rapid recognition of pseudo-occlusion and subsequent surgical or endovascular intervention may improve outcome [1,8]. The addition of a temporal dimension provided by 4D CTA provides a noninvasive means of dynamic image acquisition —similar to the dynamic imaging afforded by traditional DSA. Because 4D CTA images are acquired late into the venous phase, contrast runoff can proceed distally, even if delayed by severe stenosis. In this manner, pseudo-occlusions (in which blood flow is severely reduced or delayed) and intracranial occlusions can be identified noninvasively, thereby potentially allowing more rapid intervention aided by a clearer preprocedural understanding of the pathology.

CONCLUSION

4D CTA may be a more effective noninvasive imaging technique than traditional CTA to detect intracranial carotid artery occlusions and carotid artery pseudo-occlusions. Rapid and accurate detection of these lesions may permit more efficient intervention in the setting of acute ischemic stroke. The utility of this technique must be weighed against the risk of additional doses of radiation. Prospective comparison of this technique is warranted to confirm its validity.

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ABBREVIATIONS

AP, anteroposterior; CT, computed tomographic; CTA, CT angiography; CTP, CT perfusion; DLP, dose length product; DSA, digital subtraction angiography; ICA, internal carotid artery; TOF, time-of-flight.

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