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ORIGINAL ARTICLE

Diagnostic yield of CT angiography performed for suspected cervical artery dissection in the emergency department

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Abstract

Background and purpose Computed tomography angiographies are frequently performed in the emergency department (ED) for the assessment of cervical artery dissection (CeAD) due to the high risk of associated morbidity, but their diagnostic utility is not fully evaluated. We assessed the radiological outcomes and clinical correlates of CTAs performed for suspected CeAD.

Materials and methods CTAs for all indications ($Indication_{ALL}$) over a 10-year period were evaluated to identify those with CeAD. A subgroup of CTAs performed for suspected CeAD ($Indication_{DISSECTION}$) was identified and further assessed for clinical findings predictive of CeAD. Magnetic resonance angiography/fat-saturated images (MRA/FSI) performed after CTA were also assessed.

Results Nine-thousand-two-hundred-four CTAs were performed by our ED for $Indication_{ALL}$ of which 850 (9.2%) were for $Indication_{DISSECTION}$. CeAD was noted in 1.5% (142/9204) among $Indication_{ALL}$ and in 6.1% (53/850) of $Indication_{DISSECTION}$ CTAs. The most common radiological findings were mural thrombus and eccentric lumen. In the $Indication_{DISSECTION}$ group, new headache (OR: 2.5, 95%CI: 1.2–5.7) and partial Horner syndrome (OR: 14.4, 95%CI: 4.2–49.9) predicted carotid dissection and cervical fracture (OR: 5.5, 95%CI: 2.1–14.6) predicted vertebral artery dissections. MRA/FSI confirmed CeAD in all positive cases, but in 2 CTAs read as negative, MRA/FSI was positive for vertebral artery dissection.

Conclusion Although the yield of CTAs for clinically suspected CeAD is low, the paucity of reliable clinical predictors, high risk of morbidity, availability in ED, and comparable performance to MRA/FSI justifies its widespread utilization for initial diagnosis of CeAD.

Keywords Computed tomography angiography · Magnetic resonance angiography · Dissection · Vertebral artery · Internal cranial artery · Diagnostic yield

Abbreviations

FSI Fat-suppressed image
CeAD Cervical artery dissection
VA Vertebral artery
ED Emergency department

Introduction

CeAD is a major cause of stroke in young and middle-aged patients and is associated with an increased risk of stroke [1]. Making a timely diagnosis is critical in the ED in order to initiate early treatment and minimize potential morbidity and mortality of the disease [2]. CeAD can present with minor to more severe symptoms. Any combination of symptoms such as headache, facial pain or paresthesia, neck pain, Horner syndrome, any signs of cerebral ischemia, and history of trauma can lead to clinical suspicion for CeAD [1, 3]. Hospital-based series have demonstrated up to 60–80% of patients developing stroke after CeAD, underscoring the

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importance of making this diagnosis in a timely fashion [4, 5].

To confirm the diagnosis of CeAD, clinicians rely on imaging. Historically conventional angiography has been the gold standard for detecting CeAD [6, 7]. However, nowadays, computed tomography angiography (CTA) and magnetic resonance angiography (MRA) are now the preferred modalities in the ED due to their non-invasive nature [6, 8]. CTA of the neck enables thin section acquisition with rapid scan time, resulting in excellent spatial resolution; is universally accessible; and images closely mirror those of catheter angiography. On the other hand, MRA of the neck with non-contrast axial T1 fat suppression provides improved contrast resolution with greater sensitivity for detecting intramural thrombosis/hematoma [6]. Several previous case–control studies have shown that for the detection of CeAD, both CTA and MRA/FSI perform equally well [6, 8]. However, emergency departments at most institutions perform CTA as the initial imaging test because of the widespread availability and rapid patient turnaround times. MRA/FSI is usually reserved for the cases which have high clinical suspicion with negative or equivocal CTA [7].

Despite the extensive use of CTAs as the initial imaging test for detection of CeAD in the ED, to our knowledge, there have been no previous studies focusing on their radiological outcomes or clinical correlates predictive of dissection. Accordingly, our purpose for this study was to assess the radiological outcomes and clinical correlates of CTA performed for suspected CeAD in the emergency room setting.

Materials and method

Institutional Review Board approval was obtained for this retrospective study of adult patients with a waiver of informed consent.

Data collection

Radiology reports of CTAs performed for all indications ($Indication_{ALL}$) by our ED over a 10-year period (between 2011 and 2020) were reviewed for the presence of CeAD. The main indications included signs and symptoms of stroke, dizziness, headache, trauma, intracranial hemorrhage, or mental status change with suspicion of vessel occlusion, stenosis, aneurysm, or dissection. All the CTAs were performed at a major (approximately 700 hospital bed) academic medical center serving a large metropolitan area in the northeast of the USA. Our hospital is a level 1 trauma and comprehensive referral center with approximately 56,000 ED visits per year.

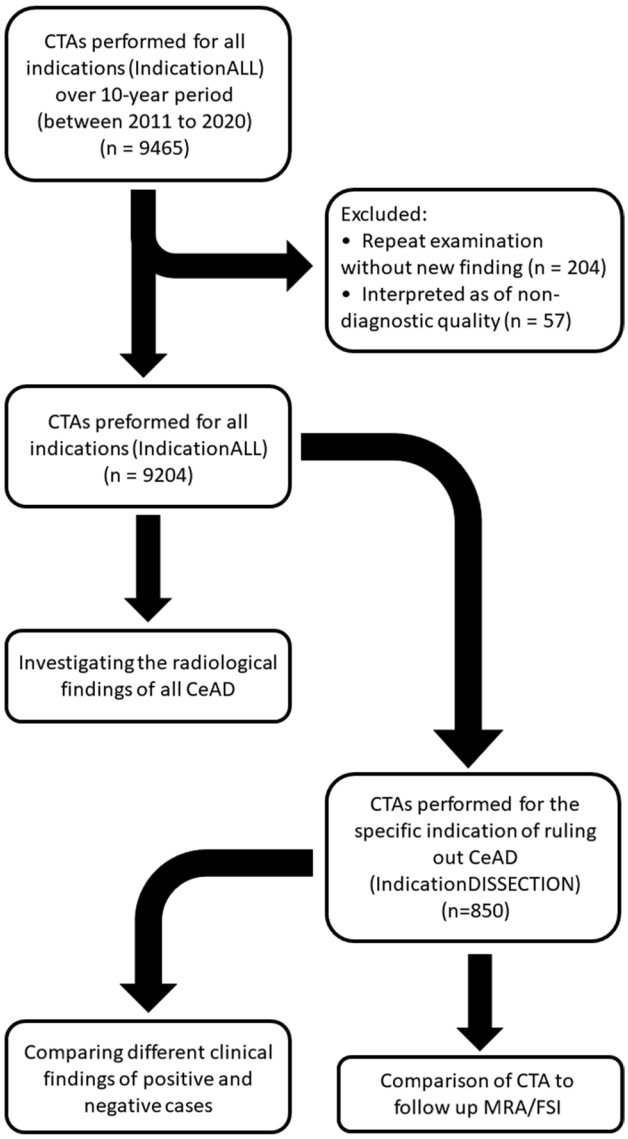

Fig. 1 Flow chart of the data collection procedure

All the CTAs were interpreted by neuroradiologists with a certificate of added qualification in Neuroradiology from the American Board of Radiology. Images for CTA's read as positive for CeAD were again reviewed by two CAQ neuroradiologists by consensus to further assess the various imaging features of dissection. Images for the CTAs read as negative for CeAD were not reviewed (Fig. 1).

Subsequently, the second group of CTAs was identified, obtained only for the indication of CeAD ($Indication_{DISSECTION}$). Electronic medical records were reviewed in detail for this smaller group to obtain available history and clinical findings. For this group, any MRA/FSI images obtained (during the same hospital visit and irrespective of the CTA results) were also assessed to determine their additional value.

Imaging technique All the CTAs were performed on a dedicated ED scanner (GE Discoveries series, GE Healthcare, Milwaukee, Wisconsin). The scan range was from the carina to the skull base or top of the cranium if the head was included. Scan parameters were set to 120 kVP 400 mAs with 1.25 mm slice reconstruction, and all patients received an 80 to 150 ml IV injection of Omnipaque 350 (GE Healthcare, Milwaukee, Wisconsin) followed by a saline flush. MRA/FSI examinations were performed on either a 1.5 T or 3 T Signa HDx scanner (GE Healthcare, Milwaukee, Wisconsin) or a 1.5-T Magnetom Espree scanner (Siemens Healthcare, Erlangen, Germany). The MRA protocol contained 2d TOF MRA of the neck, axial T1w fat-saturated images through the entire neck, followed by a dynamic MRA of the neck after administration of Multihance intravenous contrast.

Imaging review

The images of the CTA of the neck of patients with a positive diagnosis of CeAD in their radiology report were reviewed by two Board-Certified Neuroradiologists with CAQ in Neuroradiology. As described in the previous reports [9–13], the presence of the following imaging features related to CeAD were evaluated:

- Tapering eccentric narrowing (Fig. 2A)
- Mural thrombus; defined by eccentric thickening of the arterial wall with imaging characteristics compatible with acute or subacute bleeding within the thickened wall (Fig. 2B)
- Intimal flap (Fig. 2C)
- Pseudoaneurysm; defined by a focal enlargement of the arterial lumen and external diameter (Fig. 2D)

CTA was considered positive for CeAD if either tapering eccentric narrowing, mural thrombus, intimal flap, or pseudoaneurysm was present in the extracranial part of ICA or VA. In addition, images of patients with ICA and VA occlusion were individually reviewed. If the ICA or VA occlusion was distal to the origin and demonstrated a tapered, narrowed appearance without subsequent reconstitution of flow, the occlusion was determined to be secondary to a dissection. Additional perivascular soft tissue density surrounding the ICA was also determined to be an imaging characteristic suggestive of a dissection. If the occluded vessels demonstrated areas of intermittent reconstitution of flow

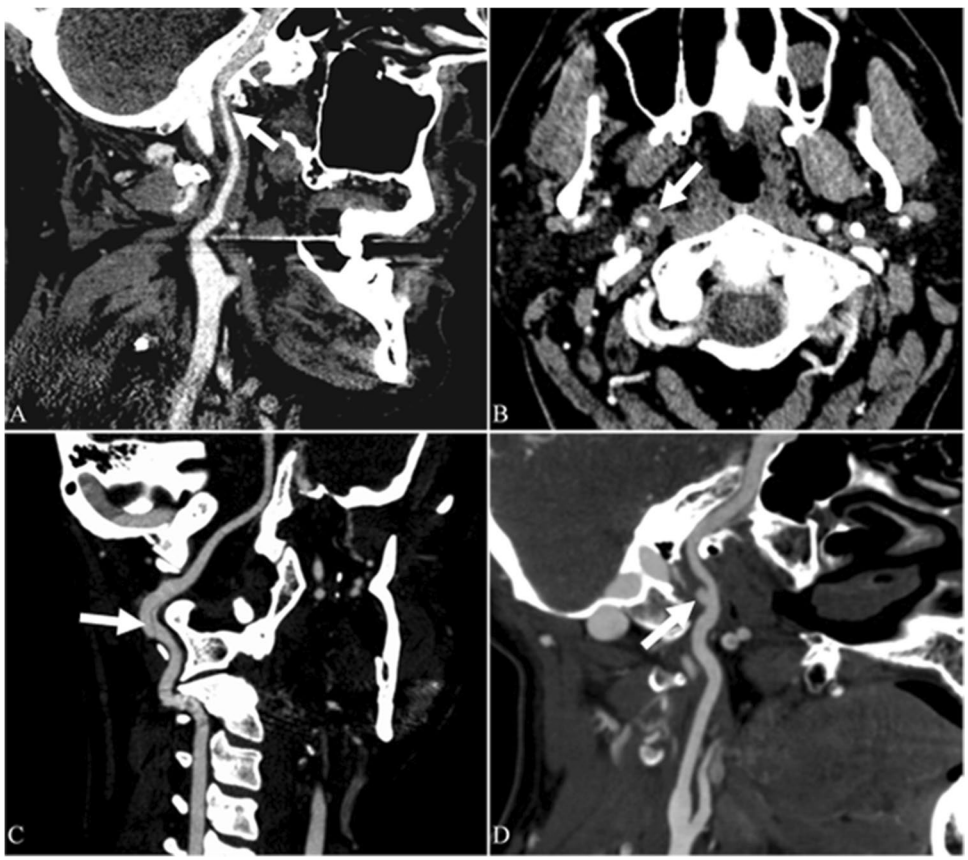

Fig. 2 CT angiography of 4 different patients shows different radiological signs of CeAD: **A** Curved reformat of right ICA shows a tapering narrowing of the lumen. **B** Axial CT angiography of the neck shows a mural thrombosis (arrow) in right ICA. **C** Curved reformat of right VA shows an intimal flap (arrow). **D** Curved reformat of right ICA shows a pseudoaneurysm (arrow)

and extensive calcifications, the occlusion was determined to be secondary to atherosclerotic disease.

All follow-up MRA/FSI of patients in the $Indication_{DISSECTION}$ group was also reviewed in a separate session by neuroradiologists to determine the presence or absence of CeAD.

Clinical review

Electronic medical records of patients in the $Indication_{DISSECTION}$ group were reviewed in detail to record demographic information such as age and sex. Information on clinical symptoms and signs recorded by the ED physicians or contemporaneous/subsequent neurology notes were also collected.

Statistical analysis

Data were analyzed using SPSS Statistics for Windows, fifteenth version (IBM corp., Armonk, NY, USA). Continuous variables were tested using the independent student *t*-test. Categorical variables were described using frequencies and percentages and compared with a chi-square or Fisher's test with the calculation of odds ratio and confidence interval. Significant features are defined as $P < 0.05$ after correction for multiple comparisons.

Results

After excluding CTAs, which were initially interpreted as non-diagnostic quality or repeat examinations without new findings, there were 9204 CTAs in the $Indication_{ALL}$ and 850 CTAs in $Indication_{DISSECTION}$ groups (Fig. 1). In the $Indication_{ALL}$ group, the mean age of subjects was 61.3 (SD ± 18.2) years, of whom 54.4% were female. 850/9204 (9.2%) CTAs were in the $Indication_{DISSECTION}$ group with a mean age of 55.5 (± 18.4) years, of whom 62.0% were female. Patients with ICA dissection or VA dissection were younger than those without dissection, but the differences were not significant. (47.0 vs. 52.9 years, p-value = 0.11 and 47.9 vs. 52.9 years, p-value = 0.19 respectively). No significant differences were seen regarding gender between patients with ICA dissection or VA dissection compared to those without.

Radiological outcomes

142/9204 (1.5%) CTAs in the $Indication_{ALL}$ group were found to have CeAD. More than one cervical artery was involved in 4 CTAs (Table 1). The positivity rate for CeAD in the $Indication_{DISSECTION}$ group specifically performed to exclude dissection was 53/850 (6.2%), which was significantly higher than that in the $Indication_{ALL}$ group ($p < 0.001$). Multiple arteries were involved in 3 CTA's of patients in the $Indication_{DISSECTION}$ group (Table 1). The CeAD affected ICA and VA nearly equally in both groups (Table 1).

Table 1 Results of CTA for CeAD in all subjects ($Indication_{ALL}$) ($n = 9204$) and subjects with specific indication of ruling out CeAD ($Indication_{DISSECTION}$) ($n = 850$)

	$Indication_{ALL}$ ($n = 9204$)	$Indication_{DISSECTION}$ ($n = 850$)
ICA dissection, *n* (%)	72 (0.8)	30 (3.5)
VA dissection, *n* (%)	74 (0.8)	26 (3.1)
Any dissection, *n* (%)	142 (1.5)[$]	53 (6.2)[*]

[$] Four patients have ICA and VA dissection

[*] Three patients have ICA and VA dissection

Table 2 Radiologic finding in CeAD in CTA in all positive cases ($n = 142$) for all indications ($Indication_{ALL}$)

Radiologic findings of positive cases	Frequency
Tapering eccentric narrowing, *n* (%)	115 (81.0)
Mural thrombosis, *n* (%)	119 (83.8)
Intimal flap, *n* (%)	51 (35.9)
Pseudo aneurysm, *n* (%)	19 (13.4)
Occlusion, *n* (%)	10 (7.0)

The imaging findings of positive cases are summarized in Table 2. The most frequently encountered diagnostic neuroimaging pattern included mural thrombosis (83.8%) and tapering eccentric narrowing of the lumen (81.0%).

Clinical correlates of CeAD

The clinical findings noted in patients with CTAs positive or negative for CeAD in CTAs performed with the specific and only indication of dissection ($Indication_{DISSECTION}$ group) are shown in Table 3. New headache, neck pain, and recent neck trauma were the most commonly reported symptoms. Patients with new headaches were 2.6 times ($p = 0.02$), and partial Horner syndrome was 14.4 times ($p < 0.01$) more likely to have carotid artery dissection. Similarly, patients with cervical fracture were 5.5 times ($p < 0.01$) more likely to have VA dissection. No other clinical findings were able to predict the presence of CeAD on CTA (Table 3). After performing logistic regression analysis, new headache and partial Horner syndrome were the only clinical findings that were significant for the presence of ICA dissection (p-value = 0.03 and p-value < 0.01, respectively). The cervical fracture was the only significant clinical finding for VA dissection after logistic regression (p-value < 0.01).

Table 3 Clinical findings in ICA and VA dissection

	ICA				VA			
	Dissection	Without dissection	OR (95%CI)	*p* value	Dissection	Without dissection	OR (95%CI)	*p*value
Gender (female)	55.2%	62.1%	0.8 (0.4–1.6)	0.45	53.8%	62.2%	0.7 (0.3–1.6)	0.39
New headache	69.0%	46.6%	2.6 (1.2–5.7)	0.02	50.0%	47.3%	1.1 (0.5–2.4)	0.78
Neck pain	44.8%	52.0%	0.8 (0.4–1.6)	0.45	53.8%	51.6%	1.1 (0.5–2.4)	0.83
History of recent trauma to the neck	32.1%	27.3%	1.3 (0.6–2.8)	0.57	30.8%	27.4%	1.2 (0.5–2.8)	0.70
Cervical fracture	0.0%	6.2%	1.0 (0.9–1.0)	0.40	24.0%	5.4%	5.5 (2.1–14.6)	<0.01
Facial pain or numbness or weakness	20.7%	14.6%	1.5 (0.6–3.8)	0.42	11.5%	14.9%	0.8 (0.2–2.5)	0.79
Dysarthria or hoarseness	3.4%	5.3%	0.7 (0.1–5.0)	1.00	11.5%	4.9%	2.5 (0.7–8.8)	0.14
Dizziness or vertigo	20.7%	32.8%	0.5 (0.2–1.3)	0.17	19.2%	32.8%	0.5 (0.2–1.3)	0.14
Nausea or vomiting	3.4%	17.2%	0.2 (0.1–1.3)	0.07	11.5%	16.9%	0.6 (0.2–2.2)	0.60
Dysphagia	0.0%	1.3%	1.0 (0.9–1.0)	1.00	3.8%	1.2%	3.2 (0.4–26.3)	0.29
Diplopia	3.4%	6.7%	0.5 (0.1–3.8)	0.72	7.7%	6.6%	1.2 (0.3–5.1)	0.69
Hemiplegia or hemiparesis	6.9%	2.8%	2.6 (0.6–11.4)	0.21	3.8%	2.9%	1.3 (0.2–10.2)	0.55
Disequilibrium	6.9%	9.2%	0.7 (0.2–3.1)	1.00	11.5%	9.0%	1.3 (0.4–4.5)	0.72
Unilateral sensory symptoms in limbs	20.7%	14.4%	1.6 (0.6–3.9)	0.42	15.4%	14.6%	1.1 (0.4–3.1)	0.78
Partial Horner syndrome	13.8%	1.1%	14.40 (4.15–49.92)	<0.01	3.8%	1.5%	2.70 (0.34–21.58)	0.34

Table 4 The outcome of follow-up MRA/FSI after CTA for subjects with specific indication of ruling out CeAD ($Indication_{DISSECTION}$)

	Results on CTA	CTA (out of 850)	Follow-up MRA/FSI (out of 48)	MRA/FSI results
ICA dissection	Positive, *n* (%)	30 (3.5%)	5 (10.4%)	All positive
	Negative, *n* (%)	820 (96.5%)	43 (89.6%)	All negative
VA dissection	Positive, *n* (%)	26 (3.1%)	8 (16.7%)	All positive
	Negative, *n* (%)	824 (96.9%)	40 (83.3%)	2 positive/ 38 negative

Correlation of MRA/FSI after CTA

48/850 patients with CTAs in the $Indication_{DISSECTION}$ group had follow-up MRA/FSI. MRA/FSI was concordant for all cases determined to be positive or negative on CTA for carotid dissection (Table 4). MRA/FSI confirmed the VA dissection in all positive cases. However, in 2/40 CTAs read as negative for VA dissection, MRA/FSI was positive (Table 4).

Discussion

Our study is one of the largest retrospective studies to evaluate the diagnostic utility of urgent CTA for assessing CeAD. We observed that the rate of CeAD among CTAs performed for all indications is around 1.5%; however, the positivity rate significantly increases to 6.2% when clinicians are suspicious of dissection based on clinical history. Among the clinical findings in CTAs performed when clinicians strongly suspected dissection, new headache and partial Horner syndrome were the only significant predictors for carotid artery dissection, and the cervical fracture was the lone significant predictor for VA dissection. Finally, our results showed that CTA is comparable to MRA/FSI for the detection of carotid dissection, with MRA/FSI having no significant added value. However, we did find that two VA dissections were missed on CTA, which were detected on subsequent MRA/FSI due to the presence of mural thrombus. Thus, we believe that MRA/FSI should be considered for further assessment in cases of strong clinical suspicion for VA dissection, such as in patients with acute vestibular syndrome and concern for posterior circulation stroke.

Early diagnosis of CeAD is critical for implementing stroke prevention strategies and early neurology subspecialty consultation [14–16]. Misdiagnosis of CeAD in the ED has been well documented [17], leading to patient morbidity. Headache, neck pain, partial Horner syndrome, pulsatile tinnitus, and signs and symptoms of cranial nerve palsy (such as diplopia, facial numbness, facial weakness, tinnitus, vertigo, hoarseness, and dysphagia) all have been described as signs and symptoms of possible CeAD [18–20]. However,

there is no clear consensus on the predictive value of these clinical factors. Similarly, in the analysis of our population, there was a significant paucity of predictive clinical factors for CeAD, with only headache and partial Horner syndrome predictive of ICA dissection and cervical spinal fracture predictive of VA dissection. Interestingly, neck pain, a common indication for CeAD in our study, was not determined to be a significant predictor of CeAD. Given the retrospective nature of our study, the specific characteristics of neck pain could not be determined. It is possible that certain clinical subtypes of neck pain, such as acute/new onset or focal laterality, could be more predictive of the presence of CeAD.

The incidence of CeAD has been reported to be as low as 2.6–3/100,000 people in the general population [1]. However, our study is the first to report and separate the prevalence of dissection in CTA's performed for patients for all indications from the prevalence of dissection in CTA's performed in patients with a clinical suspicion for dissection. This distinction is critical given that the optimal utilization of a diagnostic test is a subject of controversy among experts. A low yield diagnostic test could be considered reasonable if a missed diagnosis has devastating repercussions, such as CT for bony cervical injuries, where a 4% positive yield is regarded acceptable to some [21]. As a result, we argue that the 6.2% yield seen in our study is justified, given the morbidity of missing major arterial damage during clinical assessment. The overall lack of reliable clinical predictors for CeAD coupled with the morbidity associated with misdiagnosis justifies the widespread clinical use of CTA for dissection in the ED setting.

The most common clinical finding in our patients with ICA dissection was headache (69%) and in patients with VA dissection was neck pain (54%) which is in line with the literature [22–24]. Also, in line with other studies, our results showed that partial Horner syndrome was significantly more prevalent in patients with ICA dissection [18, 25, 26]. Partial Horner syndrome is characterized by miosis, ptosis, and enophthalmos, as opposed to Horner syndrome, which also includes anhidrosis. Patients with ICA dissection without ischemic events are more likely to develop Horner syndrome than those who have had a stroke or TIA, according to previous research [18, 27]. Horner syndrome potentially signals a milder form of ICA dissection, potentially due to the hematoma's position in the more outer layers of the arterial wall [26].

Almost a third of the patients in our study had reported prior trauma to the neck. Trauma can cause vessel wall damage [28]. Previous studies have demonstrated blunt trauma as a risk factor for cerebrovascular injury [29], but the severity of the trauma that can cause the event has been a matter of debate [30]. Our study failed to show any significant difference between the rate of prior trauma in patients with dissection and without dissection. Given the retrospective nature of this study, no distinction could be made between minor or major traumatic injuries based on clinical history. However, the presence of cervical fracture is an objective indicator of major trauma. The cervical fracture was the only significant predictor of VA dissection in our study. The cervical vertebral fracture can accompany VA dissection, specifically when it involves the transverse foramen [31]. Other authors have reported that cervical vertebral fractures or positive objective neurological signs are significant predictors for VA dissection [30].

The availability of CTA technology in the USA in emergency departments is almost universal, with 24-h access [32]. The resource-intensive nature of MRI in an ED setting, including increased time, hardware, and expertise for implementation, makes it impractical to offer as a routine service in this setting. Our study has suggested that CTA is adequate in effectively diagnosing CeAD with very little added benefit from MRA/FSI. The excellent spatial resolution of CTA to detect abnormal vessel contour, tapering eccentric narrowing of the lumen, and mural thrombosis increase diagnostic confidence for that of CeAD. Although MRA/FSI effectively demonstrates an intramural hematoma, circumstances that cause intrinsic T1 hyperintensity within the vessel can lead to confusion, such as thrombus within the lumen [33]. Lack of T1 fat-saturated signal for acute dissections or obscuration of the mural hematoma from intraluminal thrombus may even lead to a preference for CTA over MRA/FSI for some clinicians [33, 34].

Our study demonstrated 100% concordance for cases determined to be positive for dissection on CTA with the subsequent MRA/FSI. Interestingly, we did observe 2 cases out of 40 where the CTA was determined to be negative for dissection. However, the MRA/FSI ultimately was positive for VA dissection. Although our numbers are small, performing MRA/FSI may be an added benefit if there is high clinical suspicion for VA dissection and the preceding CTA is negative.

Completely occluded vessels create a diagnostic dilemma for the detection of CeAD for Radiologists. In our study, we determined ICA or VA occlusion to be secondary to a dissection if the occlusion was distal to the origin, demonstrated a gradual narrowing/tapering, presence of perivascular soft tissue density (for ICA dissections), and lack of reconstitution of flow or extensive atherosclerotic calcifications. Additional clinical factors such as acute neck pain, cervical fractures, or correlation with any available prior exams can also be helpful for the determination of acute CeAD.

The limitations of our study include the retrospective nature of our conducted study. Retrospective study limits assessment of presenting clinical symptoms; however, a large number of subjects give us insight into how to increase the specificity of the clinical evaluation in the emergency

room setting as a future direction of research. Another limitation of this study could be that providers may have considered dissection while ordering the CTA without expressing it as one of their differentials in the indication; however, considering the importance and urgency of the diagnosis, we believe it would have been an exception, if at all. Although all of the CTAs were final reported by CAQ neuroradiologists, we could not completely rule out the possibility of false negatives as those studies reported as negative were not re-reviewed. Additionally, MRA/FSI of the neck is not performed routinely as part of our institutions' diagnostic algorithm for workup of CeAD and, therefore, may reflect some bias as many of these cases may have inherent complexity associated with them.

Future directions include performing a cost-effective analysis to see the economic impact of widespread CTA in the ED setting for CeAD. Additionally, a randomized, prospective, blinded study could be performed to assess the diagnostic accuracy of CTA vs. MRA/FSI for dissection in the ED patient population.

Conclusions

In conclusion, although the yield of CTAs for clinically suspected CeAD is low, the paucity of reliable clinical predictors, high risk of morbidity, availability in ED, and comparable performance compared to MRA/FSI justifies its widespread utilization for initial diagnosis of CeAD.

Author contribution Seyed Amir Ebrahimzadeh MD, MPH: study design, data collection, statistical analysis, manuscript preparation, and editing; Komal Manzoor MD: data collection; Jonathan A. Edlow MD: manuscript preparation, and editing; Magdy Selim MD, PHD: manuscript preparation, and editing; Yu-Ming Chang MD, PHD: conceptualization, study design, and manuscript editing; Rafeeque A. Bhadelia MD: conceptualization, study design, data collection, manuscript preparation, and editing; Pritesh Mehta MD: conceptualization, study design, manuscript preparation, and editing.

Declarations

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The Human Investigation Committee (IRB) of Beth Israel Deaconess Medical Center approved this study.

Informed consent For this type of study, formal consent was not required and was waived by the institutional review board.

Conflict of interest The authors declare that they have no conflict of interest.

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