



Imaging of Spontaneous and Traumatic Cervical Artery Dissection

Comparison of Typical CT Angiographic Features

Peter B. Sporns¹ · Thomas Niederstadt¹ · Walter Heindel¹ · Michael J. Raschke² · René Hartensuer² · Ralf Dittrich³ · Uta Hanning^{1,4}

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Abstract

Introduction Cervical artery dissection (CAD) is an important etiology of ischemic stroke and early recognition is vital to protect patients from the major complication of cerebral embolization by administration of anticoagulants. The etiology of arterial dissections differ and can be either spontaneous or traumatic. Even though the historical gold standard is still catheter angiography, recent studies suggest a good performance of computed tomography angiography (CTA) for detection of CAD. We conducted this research to evaluate the variety and frequency of possible imaging signs of spontaneous and traumatic CAD and to guide neuroradiologists' decision making.

Methods Retrospective review of the database of our multiple injured patients admitted to the Department of Trauma, Hand, and Reconstructive Surgery of the University Hospital Münster in Germany (a level 1 trauma center) for patients with traumatic CAD (tCAD) and of our stroke database (2008–2015) for patients with spontaneous CAD (sCAD) and CT/CTA on initial clinical work-up. All images were evaluated concerning specific and sensitive radiological features for dissection by two experienced neuroradiologists. Imaging features were compared between the two etiologies.

Results This study included 145 patients (99 male, 46 female; 45 ± 18.8 years of age), consisting of 126 dissected arteries with a traumatic and 43 with spontaneous etiology. Intimal flaps were more frequently observed after traumatic etiology (58.1% tCADs, 6.9% sCADs; $p < 0.001$); additionally, multivessel dissections were much more frequent in trauma patients (3 sCADs, 21 tCADs) and only less than half (42%) of the patients with traumatic dissections showed cervical spine fractures.

Conclusion Neuroradiologists should be aware that intimal flaps and multivessel dissections are more common after a traumatic etiology. In addition, it seems important to conduct a CTA in a trauma setting, even if no cervical spine fracture is detected.

Keywords Neuroimaging · Multidetector computed tomography · Traumatic vertebral artery dissection · Spontaneous vertebral artery dissection · Internal carotid artery dissection

Introduction

Cervical artery dissections (CAD) are considered to be either spontaneous (sCAD) or traumatic (tCAD). Whereas tCAD is usually a complication of severe blunt head and neck trauma (mainly motor vehicle accidents) [1, 2], sCAD

occurs spontaneously or may be preceded by a minor trauma, which is usually not followed by a dissection (e.g. sneezing, coughing, sport, and recreational activities) [3, 4].

Symptoms, such as unexplained neurological deficits, Horner's syndrome, neck or head pain as well as evidence of acute infarct on brain imaging can give indications of a possible CAD [5]. Screening of asymptomatic patients for the presence of tCAD after severe motor vehicle accidents is recommended [6] because early recognition of CAD has a high importance to prevent patients from the major complication of cerebral embolization and thus ischemic stroke by administration of anticoagulants.

Both senior authors (R. Dittrich and U. Hanning) contributed equally.

✉ Peter B. Sporns
peter.sporns@ukmuenster.de

Extended author information available on the last page of the article

The pathomechanism of an arterial dissection probably begins with a bleeding of the vasa vasorum into the outer layers of the arterial wall (i.e. between the media and adventitia), which allows blood to form an intramural hematoma [7]. Secondly the intramural hematoma can cause a rupture of the intima, which is often called an intimal flap [8].

Even though the historical gold standard for detection of CAD is still a 4-vessel biplanar cerebral catheter angiography, advances in computed tomography (CT) and magnetic resonance imaging (MRI) technology make them a reliable non-invasive alternative [9, 10]. Modern trauma management requires multislice CT and especially in polytraumatized patients with high speed trauma, CT including CTA should be part of the initial work-up [11–13]. This is why CTA is much more frequently used, especially in the settings of acute stroke triage and in emergency trauma care [14], whereas for spontaneous dissection MRI and CTA have similar diagnostic performances [11].

We conducted this research to evaluate the variety and frequency of possible imaging signs of sCAD and tCAD in CTA and to determine their predictive values regarding a final dissection. The primary goal of this study was to compare typical CT angiographic features of traumatic and spontaneous CAD.

Methods

Study Population

We conducted a retrospective review of the database of multiply injured patients admitted to the Department of Trauma, Hand, and Reconstructive Surgery of the University Hospital Münster in Germany (a level 1 trauma center) (2008–2015) with tCAD. At our department, CTA is part of the initial trauma management in polytraumatized patients after high speed trauma. For comparison, we retrospectively studied our stroke database (2008–2015) for patients with sCAD. Only patients with (1) clinically suspected CAD, (2) and radiological evidence for a CAD in CTA were included for further analysis. A CAD was clinically suspected when two of the following three signs were observed: ipsilateral neck pain, headache and Horner's syndrome [4]. Radiological evidence for cervical dissection was defined when at least one of the sensitive (vessel stenosis or occlusion and irregularities of the vessel wall) and one of the specific imaging signs (intimal flap, intramural hematoma) were present.

CT/CTA Parameters

The CT/CTA scans were performed on 128-slice dual-source CT scanners (Siemens Somatom Definition AS and Definition Flash; Siemens Medical Solutions, Forchheim, Germany). Non-contrast head images were obtained from the vertex to the skull base (120kV, 340mAs, 5.0-mm slice reconstruction, 1.0-mm increment, 0.6-mm collimation, 0.8 pitch, and H30s soft kernel). This was followed by CTA (120kV, 175mAs, 1.0-mm slice reconstruction, 1-mm increment, 0.6-mm collimation, 0.8 pitch, H20f soft kernel, 80mL Ultravist 370 and 50ml NaCl flush at 4ml/s, scan start 6s after bolus tracking at the level of the ascending aorta). The scanning was triggered by the CT technologist on the basis of contrast enhancement in the aortic arch following administration of 80ml of Ultravist with a concentration of 350mg I/ml (Bayer, Leverkusen, Germany) at a rate of 4–5 ml/s. The CT angiographic source images were post-processed to create coronal and sagittal reformatted images with a 1-mm section thickness, maximum intensity projection (MIP) images and curved planar reformatted images of the bilateral common and internal carotid and vertebral arteries. All datasets were reconstructed with a sinogram affirmed iterative reconstruction (SAFIRE) algorithm.

Image Evaluation

All CT images were independently reviewed by two experienced neuroradiologists and in a blinded fashion. All imaging studies were examined for the presence of acute ischemic stroke and specific imaging features, i.e. intimal flap, intramural hematoma and sensitive imaging features, i.e. vessel stenosis or occlusion and irregularities of the vessel wall. Vessel wall thickening was evaluated as an enlargement of the outer diameter of the vessel on CTA typically resulting from an intramural hematoma. Vessel occlusion was defined as a lack of contrast filling of the affected vessel and vessel stenosis was defined as a lumen irregularity clearly visible by the naked eye. We defined the presence of dissection when at least one of the sensitive and specific imaging signs was present. Due to the fact that some patients had multivessel CADs, this was performed on a vessel by vessel basis rather than on a case by case basis.

Statistical Analysis

Univariable distribution of metric variables is described by median and interquartile range (IQR). For categorical data, absolute and relative frequencies are given. Differences between spontaneous and traumatic CAD and between locations of the dissections in the internal carotid arteries

Table 1 Baseline clinical characteristics of the study population

Characteristics	All patients (<i>n</i> = 145)	Spontaneous cervical artery dissection (<i>n</i> = 40)	Traumatic cervical artery dissection (<i>n</i> = 105)	<i>P</i> value
Age (years, mean \pm SD)	45.4 \pm 18.8	46.3 \pm 9.5	45.0 \pm 21.3	0.670
Sex, male, <i>n</i> (%)	99 (68.3)	29 (72.5)	70 (66.7)	0.195
Number of dissections, <i>n</i> (%)	169	43 (25.4)	126 (74.6)	N/A
Multivessel dissection, <i>n</i> (%)	24	3 (7.5)	21 (20.0)	0.116
Localization of cervical artery dissection				
Internal carotid arteries (ICA) <i>n</i> (%)	91 (53.8)	29 (67.4)	62 (49.2)	0.038
Vertebral arteries (VA), <i>n</i> (%)	78 (46.2)	14 (32.6)	64 (50.8)	

N/A not applicable

Table 2 Agreement between reviewers

	Rater agreement κ
Smooth vessel stenosis	0.854
Vessel occlusion	0.959
Lumen irregularity	1.000
Intimal flap	0.845
Intramural hematoma: wall thickening (CT)	0.815

(ICA) versus vertebral arteries (VA) were compared using Student's *t* test (normal distribution) and Mann-Whitney U-test (non-normal distribution) for quantitative variables and the χ^2 -test for categorical variables. Results of the detected characteristic imaging findings were compared for each reader and κ -statistics were utilized to detect the interobserver agreement. Because interobserver agreement proved to be high, the few discrepancies were then resolved by mutual consensus. For all analyses two-tailed *p*-values were used, and *p* < 0.05 was regarded as significant. Statistical analyses were performed in SPSS version 24 (IBM Corporation, Armonk, NY).

Results

A total of 145 patients were included in our study (99 male, 46 female; 45 \pm 18.8 years of age), consisting of 126 dissected arteries with a traumatic (62 ICA and 64 VA) and 43 with a spontaneous etiology (29 ICA and 14 VA). In 24 patients multivessel CADs were detected (3 sCADs, 21 tCADs) (Table 1). Of the patients with spontaneous etiology 27 had risk factors for vascular disease, such as arterial hypertension, hyperlipidemia, diabetes mellitus, obesity and smoking. The clinical presentation varied from local symptoms, such as headaches, neck or facial pain, Horner's syndrome, tinnitus or cranial nerve deficits (*n* = 16) to temporary neurological deficits (*n* = 3) and symptoms and radiographic evidence of cerebral infarction (*n* = 24).

In contrast to patients with sCAD 54 out of 126 patients with tCAD (42.9%) had combined cervical vertebral fractures. Additionally, the difference in the frequency of ver-

tebral fractures was statistically significant between ICA (19.4%) and VA (65.5%) CADs (*p* < 0.001). Altogether, the interobserver agreement between the two neuroradiologists concerning the detection of radiologic features was high (κ > 0.8; Table 2).

The sensitive radiologic features smooth or slightly irregular tapered stenosis and lumen irregularity were detected on each sCAD (100%) and on almost every tCAD (97.6% and 98.4%, respectively). Thus, concerning the evidence of these two imaging findings there were no significant differences between both dissection etiologies (*p* = 0.228 and *p* = 0.328, respectively). Of the 43 included sCADs 14 arteries (5 ICA and 9 VA, 32.6%) were considered to be occluded and 41 (32.5%) of the 126 tCADs (12 ICA and 29 VA), consequently there were no statistically significant differences between traumatic and spontaneous CADs concerning the presence of vessel occlusions (*p* = 0.998). Intimal flaps were found in only 2/43 (4.7%) of the sCADs (2 ICA), but in 49/145 (38.9%) of the tCADs (*p* < 0.001) (Table 3); however, the frequency of occurrence of intimal flaps in all vertebral arteries was not statistically noticeable different between both etiologies (*p* = 0.065; Table 4).

The majority of all the dissected arteries whether of spontaneous or traumatic etiology, showed a specific wall thickening (intramural hematoma): 30/43 (69.8%) of all spontaneous and 84/126 (66.7%) of all traumatic CADs. In 40 (51.3%) out of 78 included VA dissections (6 sCADs, 34 tCADs) and 74 (81.3%) of 91 ICA dissections (24 sCADs, 50 tCADs) the specific sign was detected with no significant difference between dissection etiologies (VA *p* = 0.486 and ICA *p* = 0.810) (Table 3, 4 and 5).

Discussion

To our knowledge, this evaluation is the first study comparing the most relevant imaging signs of traumatic and spontaneous CAD in a large cohort of patients. We found that in patients with traumatic dissections intimal flaps are more commonly seen than in patients with spontaneous dissec-

Table 3 Comparison of imaging signs of cervical artery dissections

Characteristics	All cervical artery dissections (<i>n</i> = 169)	Spontaneous cervical artery dissections (<i>n</i> = 43)	Traumatic cervical artery dissections (<i>n</i> = 126)	<i>P</i> value
Vessel stenosis, <i>n</i> (%)	166 (98.2)	43 (100)	123 (97.6)	0.307
Vessel occlusion, <i>n</i> (%)	55 (32.5)	14 (32.6)	41 (32.5)	0.998
Lumen irregularity, <i>n</i> (%)	167 (98.8)	43 (100)	124 (98.4)	0.406
Intimal flap, <i>n</i> (%)	51 (30.2)	2 (4.7)	49 (38.9)	<0.001
Intramural hematoma: wall thickening (CT), <i>n</i> (%)	114 (67.5)	30 (69.8)	84 (66.7)	0.708

Table 4 Comparison of imaging signs of cervical dissections in the vertebral arteries

Characteristics	All dissections of the vertebral arteries (<i>n</i> = 78)	Spontaneous cervical artery dissection (<i>n</i> = 14)	Traumatic cervical artery dissection (<i>n</i> = 64)	<i>P</i> value
Vessel stenosis, <i>n</i> (%)	78 (100.0)	14 (100)	64 (100)	N/A
Vessel occlusion, <i>n</i> (%)	38 (48.7)	9 (64.3)	29 (45.3)	0.198
Lumen irregularity, <i>n</i> (%)	78 (100.0)	14 (100)	64 (100)	N/A
Intimal flap, <i>n</i> (%)	13 (16.7)	0 (0.0)	13 (20.3)	0.065
Intramural hematoma: wall thickening (CT), <i>n</i> (%)	40 (51.3)	6 (42.9)	34 (53.1)	0.486

Table 5 Comparison of imaging signs of cervical dissections in the internal carotid arteries

Characteristics	All dissections of the internal carotid arteries (<i>n</i> = 91)	Spontaneous cervical artery dissection (<i>n</i> = 29)	Traumatic cervical artery dissection (<i>n</i> = 62)	<i>P</i> value
Vessel stenosis, <i>n</i> (%)	88 (96.7)	29 (100)	59 (95.2)	0.228
Vessel occlusion, <i>n</i> (%)	17 (18.7)	5 (17.2)	12 (19.4)	0.810
Lumen irregularity, <i>n</i> (%)	89 (97.8)	29 (100)	60 (96.8)	0.328
Intimal flap, <i>n</i> (%)	38 (41.8)	2 (6.9)	36 (58.1)	<0.001
Intramural hematoma: wall thickening (CT), <i>n</i> (%)	74 (81.3)	24 (82.8)	50 (80.6)	0.810

tions, which might be a hint towards a different pathomechanism. The most commonly seen signs in CTA are vessel stenosis, lumen irregularity and intramural hematoma after both traumatic and spontaneous etiology (Fig. 1, for examples see Fig. 2a–f).

For neuroradiologists it is vital to know which imaging signs they have to look for and which sensitivity and specificity these signs have to establish a clear diagnosis of CAD. Cerebral infarction due to distal thrombus embolization is the most relevant clinical manifestation of CAD [4]. Early recognition of neurovascular trauma, close collaboration with the trauma surgeons and administration of antithrombotic treatment may preclude arterial thrombosis and thus prevent ischemic stroke. After the development of new multislice technologies, the diagnostic potential of CTA has increased because of enabling ultra-fast scanning speed, high-resolution images, and sophisticated 3D image post-processing. In our previous study we have demonstrated that CT and MRI are equally suitable for detection of CAD [11]. In this study the level of agreement between

the two neuroradiologists concerning the detection of characteristic radiological features of CAD was high, suggesting a high reliability and reproducibility of our results in clinical routine when being aware of the potential imaging occurrences of either spontaneous or traumatic CAD. Interestingly, only 42% of the polytraumatized patients with tCAD had a cervical spine fracture. A recent study by Delgado Almandoz et al. found arterial dissections by CTA in 13% of the patients with blunt head and neck trauma. They showed that particularly in trauma without any fracture but a high-impact mechanism of injury (MOI), the diagnostic yield of CTA for detecting arterial dissections is more than 10%. Among patients involved in high-speed motor vehicle accidents, CTA detected dissections in approximately 20% of patients independent of the presence of fractures [15]. This is in line with our results and suggests that it is important to conduct a CTA in a trauma setting even if no fracture is detected.

Another interesting finding of our study is that multivessel occlusions were much more frequent after a traumatic

Fig. 1 Graph showing the occurrence of imaging signs in 169 cervical artery dissections (43 spontaneous and 126 traumatic etiology)

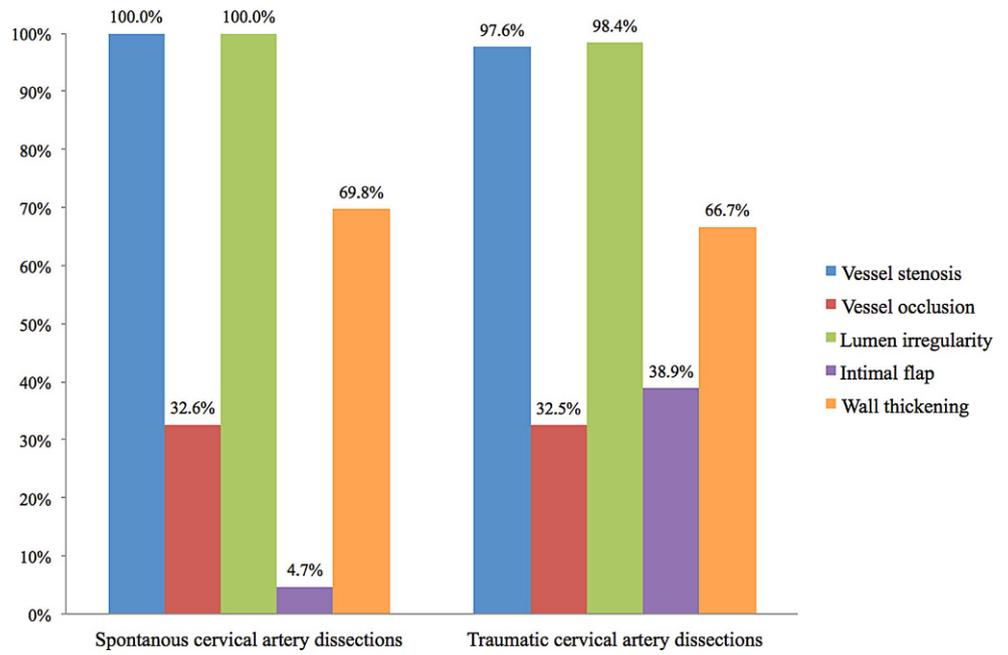
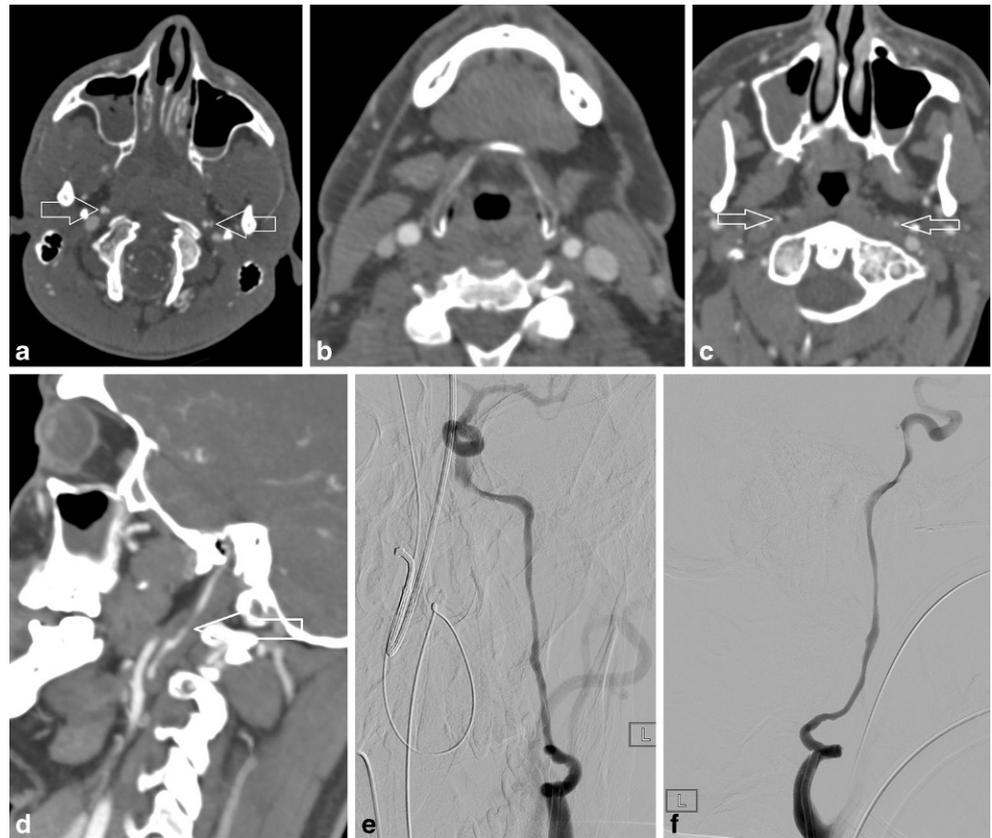


Fig. 2 Features in CT of cervical artery dissections. **a** illustrates an intimal flap, lumen irregularity and a hematoma of the arterial wall in a patient with dissection of the internal carotid artery after trauma (*arrows*); **b** shows axial CTA of a patient with traumatic etiology and normal caliber of the common carotid artery on both sides, whereas **c** illustrates high-grade stenosis and a wall hematoma of the internal carotid artery on both sides in the same patient (*arrow*). This is supported by the sagittal reformation (**d**) as well as conventional angiography of the left carotid artery (**e, f**)



etiology. Keeping this in mind the neuroradiologist should carefully examine all arteries, especially when one dissection is observed in trauma patients.

The limitations of our study are partly attributed to the retrospective single center design. Strengths include the large consecutive series of traumatic CADs which give a broad overview about the occurrence and frequency of potential imaging signs. Another advantage is the use of new generation multislice CT throughout the whole study population in comparison to most other studies using older (i.e. 16-slice) CT scanners with much lower image quality [16, 17].

Conclusion

This study gives an overview about the most relevant CT angiographic signs depending on traumatic or spontaneous CAD. Neuroradiologists should be aware that intimal flaps and multivessel dissections are more common after traumatic etiology. A correct diagnosis is crucial for the affected patients because anticoagulant treatment will be administered as embolic stroke prevention. Moreover, it seems important to conduct a CTA after high-speed trauma, even if no cervical spine fracture is detected.

Compliance with ethical guidelines

Conflict of interest P. Sporns, T. Niederstadt, W. Heindel, M. J. Raschke, R. Hartensuer, R. Dittrich, U. Hanning declare that they have no competing interests.

Ethical standards This retrospective study was approved by the Ethics Committee of the University Münster and the Westfalian Chamber of Physicians, Münster, Germany. All study protocols and procedures were conducted in accordance with the Declaration of Helsinki.

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Affiliation

Peter B. Sporns¹  · Thomas Niederstadt¹ · Walter Heindel¹ · Michael J. Raschke² · René Hartensuer² · Ralf Dittrich³ · Uta Hanning^{1,4}

¹ Department of Clinical Radiology, University Hospital Münster, Albert-Schweitzer-Campus 1, Building A1, 48149 Münster, Germany

² Department of Trauma, Hand and Reconstructive Surgery, University Hospital Münster, Albert-Schweitzer-Campus, Building W1, 48149 Münster, Germany

³ Department of Neurology, University Hospital Münster, Albert-Schweitzer-Campus 1, Building A1, 48149 Münster, Germany

⁴ Department of Diagnostic and Interventional Neuroradiology, University Hospital Hamburg-Eppendorf, Hamburg, Germany