

# Incidence of traumatic carotid and vertebral artery dissections: results of cervical vessel computed tomography angiogram as a mandatory scan component in severely injured patients

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**Purpose:** The aim of this study was to evaluate the true incidence of cervical artery dissections (CeADs) in trauma patients with an Injury Severity Score (ISS) of  $\geq 16$ , since head-and-neck computed tomography angiogram (CTA) is not a compulsory component of whole-body trauma computed tomography (CT) protocols.

**Patients and methods:** A total of 230 consecutive trauma patients with an ISS of  $\geq 16$  admitted to our Level I trauma center during a 24-month period were prospectively included. Standardized whole-body CT in a 256-detector row scanner included a head-and-neck CTA. Incidence, mortality, patient and trauma characteristics, and concomitant injuries were recorded and analyzed retrospectively in patients with carotid artery dissection (CAD) and vertebral artery dissection (VAD).

**Results:** Of the 230 patients included, 6.5% had a CeAD, 5.2% had a CAD, and 1.7% had a VAD. One patient had both CAD and VAD. For both, CAD and VAD, mortality is 25%. One death was caused by fatal cerebral ischemia due to high-grade CAD. A total of 41.6% of the patients with traumatic CAD and 25% of the patients with VAD had neurological sequelae.

**Conclusion:** Mandatory head-and-neck CTA yields higher CeAD incidence than reported before. We highly recommend the compulsory inclusion of a head-and-neck CTA to whole-body CT routines for severely injured patients.

**Keywords:** polytrauma, carotid artery, vertebral artery, dissection, blunt trauma, computed tomography angiogram

## Introduction

Missed injuries are a major concern in the management of trauma patients; in 25% of the severely injured patients, at least one diagnosis remains undetected.<sup>1</sup> Traumatic blunt carotid or vertebral artery injuries are associated with the mortality rates of up to 33% and a neurological morbidity of up to 38%,<sup>2-4</sup> but initially, a high proportion of cervical artery dissections (CeADs) remains asymptomatic.<sup>2</sup> While a contrast-enhanced multidetector computed tomography (CT) of thorax, abdomen, and pelvis is regarded as a diagnostic standard in severely and/or multiply injured patients,<sup>5</sup> no compulsory consensus exists for the routine imaging and rule out of CeAD.<sup>6,7</sup> Most of the polytrauma guidelines “recommend” a CT angiogram (CTA) in patients with an ill-defined “relevant trauma” to the head-and-neck region;<sup>8</sup> it is known that even for highly experienced trauma surgeons, prediction of blunt injuries exclusively based on history and physical examination miss ~50% of injuries,<sup>9</sup> underlining the need for

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standardized protocols and algorithms for head-and-neck CTA in trauma patients. Depending on the study population and preassessment, incidence of carotid artery dissections (CADs) and vertebral artery dissections (VADs) ranges from 1.7% and 4.9%.<sup>10,11</sup> To the best of our knowledge, there are no results reported from prospectively mandatory integration of a head-and-neck CTA into whole-body scanning routine in severely injured patients presenting with an Injury Severity Score (ISS) of  $\geq 16$ .

## Patients and methods

A total of 230 consecutive multiply injured trauma patients admitted to our Level I trauma center during a consecutive 24-month period were prospectively included. All patients underwent a standardized whole-body CT scan in a 2×128 detector row scanner (SOMATOM Definition Flash; Siemens Healthcare GmbH, Erlangen, Germany), consisting of a noncontrast head CT and a one-phase contrast-enhanced whole-body (skull vertex to middle of thigh) CT including head and neck, adhering to the national S3 – Guideline “Polytrauma/Schwerverletzten – Behandlung”.<sup>8</sup> The Independent Ethics Committee at the Regensburg University confirmed that for this specific scientific project, no ethics approval or commission’s opinion was necessary due to the fact that according to our applicable laws and guidelines, such anonymized retrospective study without any study-related clinical intervention or use of patients’ personal data does not have to be submitted to the ethics committee. Thus, no informed consent was obtained.

## CT scan protocol

Initially, a noncontrast-enhanced scan of the neurocranium was acquired in 0.75 mm slices (360 mAs, 120 kV, pitch 0.55, increment 0.75 mm, and field of view 230 mm).

Aiming at a scanning time as short as reasonably possible in the setting of a routine integration of CT into emergency room algorithms, we use a single contrast-enhanced scan from head to toe with 120 mL of contrast agent (Accupaque 350; GE Healthcare Europe GmbH, Freiburg, Germany) automatically injected, followed by a flush with 30 mL of saline, both contrast agent and saline flush with the injection rates of 3 mL/second. The scan is started at a fixed delay of 55 seconds after completing the contrast agent injection. The field of view is 500 mm, the slice thickness is 5.0 mm, the increment is 5.0 mm, the pitch is 0.60 kV, and mAs are calculated and set automatically (CARE kV and CARE Dose; Siemens Healthcare GmbH) based on the topogram. A soft-tissue kernel with medium edge attenuation (B26f medium)

was used for the calculation of axial, coronal, and sagittal views of the head and neck. Additional thick-slab axial maximal intensity projection (MIP) was rendered (10 mm) axial, sagittal, and coronal. Additional reconstruction were rendered using a B60f kernel for lung tissue (axial), a B60f sharp kernel for bones (axial and coronal, additional sagittal for spine), and a B30f kernel for soft tissue (axial, additional coronal for abdomen). Further reconstruction was calculated on the radiologists’ discretion depending on the findings or suspicions drawn from the standard datasets.

Image interpretation was performed using a standard three-monitor work station using the Syngo and Syngo. via picture archiving and communication system (PACS; Siemens Healthcare GmbH).

## Statistical analysis

For statistical calculations, analysis, and plotting, GraphPad Prism Version 5.00a for Mac (GraphPad Software, Inc., La Jolla, CA, USA) was used. Arising from the observational character of this study, mainly, descriptive statistics was used, where appropriate multivariate ANOVA with post hoc Bonferroni comparisons was conducted. Groups were compared using two-sided Student’s *t*-test.  $P < 0.05$  was considered statistically significant differences.

## Results

The study comprises 230 consecutive multiply injured trauma patients admitted to our Level I trauma center. Patients without injury of the cervical arteries were 41.8 years (median; range 1.9–90.9). A total of 155 of them were male and 59 of them were female. The mean ISS was  $32 \pm 15.1$ . Major bleeding<sup>12</sup> occurred in 31 patients (14.4%), and 24 patients died, yielding a mortality rate of 11.2%.

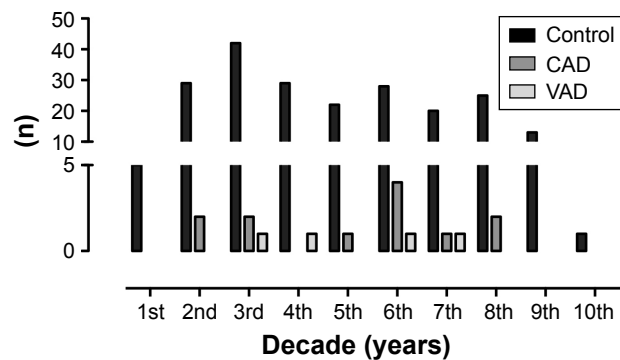
## Patient characteristics

Data on patients with CAD and VAD are listed in Table 1; age tends to be higher in patients with CAD and lower in VAD. The age distribution (Figure 1) reveals a major peak of multiply injured patients without CAD/VAD in the third

**Table 1** Data on patients, injury severity, and mortality

	Control	CAD	VAD
N	215	12	4
Age, years	41.8	52.7	44.9
(median, range)	(1.9–90.9)	(18.0–79.9)	(22.6–63.3)
Sex (m/f)	155/59	7/5	3/1
ISS (median; range)	25; 13–75	34; 17–57	39.5; 22–57
Major bleeding	31 (14.4%)	1 (8.3%)	1 (25%)
Mortality	24 (11.2%)	3 (25%)	1 (25%)

**Abbreviations:** CAD, carotid artery dissection; f, female; ISS, Injury Severity Score; m, male; VAD, vertebral artery dissection.



**Figure 1** Age distribution of multiply injured patients without blunt injury of the cervical arteries (control), with CAD, and with VAD.

**Abbreviations:** CAD, carotid artery dissection; VAD, vertebral artery dissection.

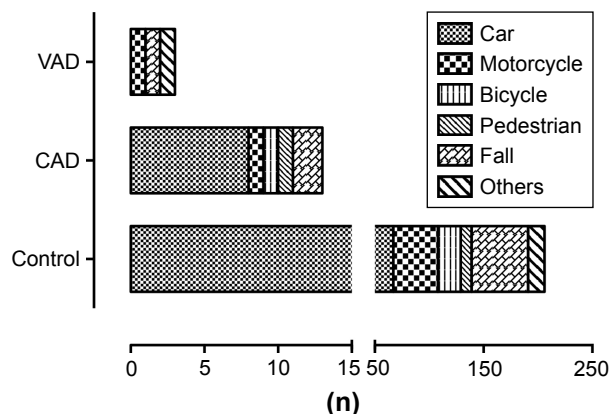
decade of life with minor peaks in the sixth and eighth decades. Patients with CAD show a definite peak in the sixth life decade, while patients with VAD are distributed equally to the third, fourth, and sixth decades.

## Trauma mechanism and severity

Analyzing the underlying trauma mechanism shows a dominance of traffic accidents in all subgroups (Figure 2); patients were most often passengers of a car, while motorcycle accidents cause the second most multiply injuries. Further cause of higher energetic trauma is falls from heights >3 m, represented in all three subgroups. Major cerebral bleeding occurred in one patient with CAD (8.3%) and one patient with VAD (25%). The injury severity in VAD is elevated to  $40 \pm 24.7$  (Figure 3).

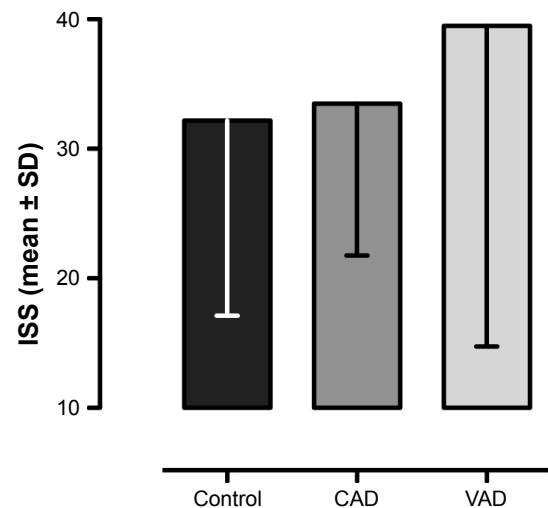
## Incidence and concomitant injuries

Of the 230 patients included, 12 (5.2%) patients had a CAD and 4 (1.7%) patients had a VAD. Therein, one patient had dissections of both carotid and vertebral arteries.



**Figure 2** Trauma mechanism of multiply injured patients without blunt injury of the cervical arteries (control), with CAD, and with VAD.

**Abbreviations:** CAD, carotid artery dissection; VAD, vertebral artery dissection.



**Figure 3** Trauma severity measured by ISS of multiply injured patients without blunt injury of the cervical arteries (control), with CAD, and with VAD.

**Note:** Values are shown as mean  $\pm$  SD.

**Abbreviations:** CAD, carotid artery dissection; ISS, Injury Severity Score; VAD, vertebral artery dissection.

While distribution of concomitant injuries does not differ in patients with and without CAD, all patients with VAD had a fracture of the cervical spine (Table 2), located at C6, C2, C5-7, and C4-5. In CAD, the fractures were located at C7, C3-T1, C1-2 and C6-7, and C4-5. While injuries to the abdominal organs are only found in 27.4% of patients without CAD/VAD, abdominal organ injury, lung injury, and traumatic brain injury are found in two of the three patients with VAD, paralleling the elevated ISS in the group with VAD.

## Therapy and outcome

In case of CAD, overall mortality is 25%. One death was caused by cerebral ischemia due to high-grade CAD (8.3%) and consecutive ischemic insult in the cerebri media territory. A total of 41.6% of patients with traumatic CAD had

**Table 2** Concomitant injuries

Injury	Control	CAD	VAD
Cervical spine fracture	42 (19.5)	4 (33.3)	4 (100)*
Thoracic spine fracture	56 (26)	4 (33.3)	0 (0)
Lumbar spine fracture	44 (20.5)	4 (33.3)	1 (33.3)
Midface and skull fractures	91 (42.3)	5 (41.7)	2 (50)
Rib fractures	107 (49.8)	3 (25)	2 (50)
Pelvic ring fracture	57 (26.5)	5 (41.7)	1 (33.3)
Upper extremity fracture	72 (33.5)	5 (41.7)	1 (33.3)
Lower extremity fracture	59 (27.4)	6 (50)	1 (33.3)
Traumatic brain injury	140 (65.1)	6 (50)	3 (75)
Lung injury	120 (55.8)	6 (50)	2 (66.6)
Abdominal organ injury	59 (27.4)	4 (33.3)	2 (66.6)

**Notes:** Absolute values, percentage in parenthesis. \* $P < 0.05$  vs control (statistically significant).

**Abbreviations:** CAD, carotid artery dissection; VAD, vertebral artery dissection.

neurological sequelae. All patients had to begin therapeutic anticoagulation therapy (100%) and one patient had to undergo interventional stent grafting of the common carotid artery (11.1%).

One of the four patients with traumatic VAD died, yielding a mortality rate of 25%. In one patient (25%), VAD caused severe neurological sequelae. All surviving patients with VAD (3/3; 100%) had to be put on therapeutic anticoagulation. No interventional therapy was conducted for VAD.

## Discussion

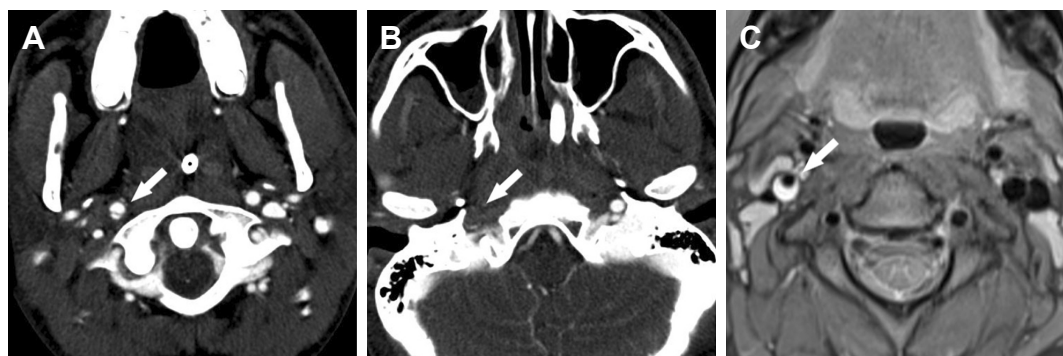
Injuries of the carotid or vertebral artery are reportedly associated with both high mortality rates and neurological morbidity rates.<sup>2-4</sup> In multiply injured patients, diagnoses and decisions only based on history and clinical examination are prone to error with missed injuries in up to 47%.<sup>9</sup> Thus, multiply injured patients at risk for carotid or VAD have to be identified via a combination of trauma and patient characteristics including the pattern of obvious injuries or all patients eligible for a whole-body CT need to be screened for carotid and vertebral artery injuries by making the CTA of supra-aortic arteries a part of the routine scan protocol.<sup>3</sup> For example, as shown in Figure 4, a young man was diagnosed with an aortic arch rupture after a motorcycle crash and was secondarily admitted to our Level I trauma center for endovascular aortic repair; the in-house control CTA revealed a missed CAD on the right.

To the best of our knowledge, we present the first data from a prospectively designed study making the head-and-neck CTA a compulsory component of whole-body scanning routine in patients presenting with an ISS of  $\geq 16$ . Our cohort did not differ significantly from larger studies targeting

multiply injured patients (ISS  $\geq 16$ ) in Germany and Western Europe regarding baseline characteristics.<sup>13,14</sup>

Within the population of severely injured patients, those with CeAD are beyond a subgroup with a mortality rate of 25% compared to 11.4% in other patients with an ISS of  $\geq 16$ . Especially in CAD, a high percentage (41.6%) of patients had severe neurological sequelae. In our study, for all patients surviving a CAD, the diagnosis of a dissection had therapeutic consequences; all were put on therapeutic anticoagulation. The best treatment option for CAD is still under debate, since anticoagulant therapy is contraindicated in some patients, fails due to recurrent ischemic strokes, or causes secondary hemorrhage.<sup>3,15</sup>

Mortality of patients with VAD was 25% in our cohort, another 25% of patients had severe neurological sequelae, and all patients surviving a VAD had to be put on anticoagulant therapy. Presumably to be attributed to the anatomy of the neck, all patients with VAD had a concomitant fracture of the cervical spine (Figure 5); movements and displacements within the physiological cervical spine range of motion (ROM) are unlikely to cause a dissection of the vertebral arteries encased in the transverse vertebral processes. By contrast, nonphysiological displacements of the cervical spine and the osseous vertebral artery canal or a direct force impact to the cervical spine are unlikely to not lead to a concomitant fracture in case of causing a VAD.<sup>16</sup> The distance between the carotid arteries and the cervical spine levers both the amount and the speed of displacement of the carotid artery centered around the spine as axis of motion. Farthest displacement of a carotid artery is achieved in a compound movement of cervical spine hyperextension and hyperrotation. This would be in line with our observation of almost exclusively single-sided CADs in our study

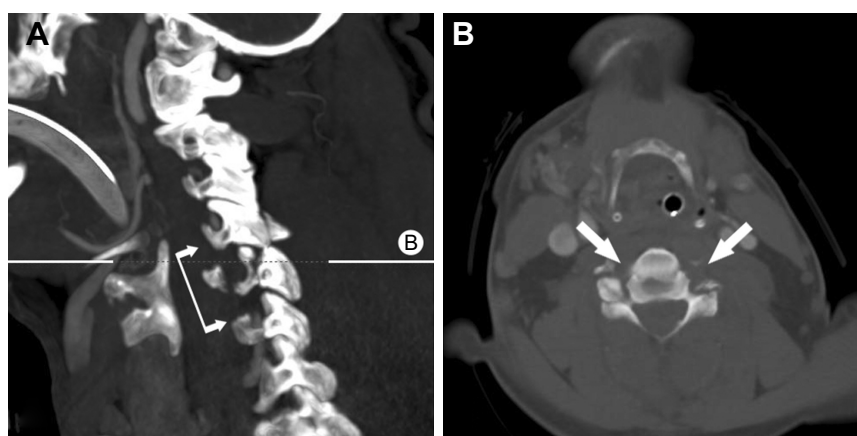


**Figure 4** Image of traumatic carotid artery dissection on the right side.

**Notes:** (A) Axial polytrauma CT clearly depicts the dissection membrane in the right internal carotid artery (arrow). (B) No flow (arrow) can be seen distal of the CAD right before entering of the carotid artery into the petrous bone. (C) PD fs axial MRI sequence, acquired 1 week later, shows the right-sided CAD revealing the hyperdense carotid wall hematoma (arrow).

**Abbreviations:** CAD, carotid artery dissection; CT, computed tomography; MRI, magnetic resonance imaging; PD fs axial, axial fat-saturated proton density.





**Figure 5** Bilateral vertebral artery dissection in cervical C5/6 facet fractures with dislocation.

**Notes:** (A) No flow in the vertebral arteries from C5 to C7 (connected arrows). B delineates plane of axial CT image B. (B) Axial CT image shows no flow in both vertebral arteries (arrows).

**Abbreviation:** CT, computed tomography.

and support the use of neck braces limiting the cervical spine ROM in high-risk populations such as race drivers and motorcyclists.<sup>17</sup>

The key finding of our study is a combined incidence of 6.5% for CAD/VAD, with CAD alone having an incidence of 5.2%, when integrating the head-and-neck CTA into routine whole-body CT protocols for severely injured patients with an ISS of  $\geq 16$ . Our values are beyond the ones reported from less strict-defined populations or even clinically preselected cohorts.<sup>10,11</sup> Our data urge the importance of a reliable rule-out of CeAD for multiply injured patients. Furthermore, from the presented data, no reliable tracers for CAD from patient characteristics or trauma mechanism can be identified, as reported before by Cook et al.<sup>16</sup> Paralleling our results, Dreger et al<sup>18</sup> found that blunt vertebral artery injuries are rarely associated with symptoms, making it difficult to expect the diagnosis and warrant proper imaging. We thus urgently recommend the obligatory integration of a head-and-neck CTA in existing handling routines. Caputo et al<sup>19</sup> concluded that the rigorous use of whole-body CT protocols yields lower mortality rates despite even higher ISS when compared with selective scanning in trauma patients.

Designed and conducted as a single-center study providing data from a 2-year time frame, population size is limited. Larger cohorts are needed to back up our observations and findings as well as to support the urge for the integration of routine head-and-neck CTA into existing whole-body CT protocols. Despite all surviving patients with CAD or VAD in our population received therapy (eg, carotid artery stent-grafting) or were put on secondary prevention measures (therapeutic anticoagulation), it is not known whether both diagnosis and treatment of CAD lead

to a reduction of mortality or neurological sequelae;<sup>20</sup> these questions remain subject to further randomized clinical trials (RCTs).

## Conclusion

Compulsory integration of head-and-neck CTA into whole-body MDCT protocols for patients presenting with an ISS of  $\geq 16$  reveals an incidence of combined 6.5% for CAD/VAD, with CAD alone having an incidence of 5.2%.

Both CAD and VAD are associated with high mortality rates of 25% and a large percentage of patients with severe neurological sequelae. Since all surviving patients are subjected to therapy, the diagnosis of CeAD must not be missed. It is not possible to identify patients with CeAD from patient characteristics, concomitant injuries, or trauma history. We thus highly urge on the integration of head-and-neck CTA into existing polytrauma MDCT protocols until further RCTs shed light on the relevance of diagnosing and treating all CeADs.

## Disclosure

The authors report no conflicts of interest in this work.

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