Journal of Experimental and Clinical Medicine
https://dergipark.org.tr/omujecm

Research Article

J Exp Clin Med
2022; 39(3): 776-780
doi: 10.52142/omujecm.39.3.35

Anatomical variations of cervical segment of internal carotid artery in patients with subarachnoid hemorrhage

Aykan ULUS [1,*], Cengiz ÇOKLUK [1], Abdullah Hilmi MARANGOZ [1], Enis KURUOĞLU [2]

[1] Department of Neurosurgery, Faculty of Medicine, Ondokuz Mayıs University, Samsun, Turkey
[2] Clinic Neurosurgery, Medicana International Samsun Hospital, Samsun, Turkey

Received: 01.04.2021 • **Accepted/Published Online:** 14.08.2022 • **Final Version:** 30.08.2022

Abstract

The cervical segment of an internal carotid artery (cICA) usually has a straight vertical course without any branching. In the present study, variations of the cICA were evaluated based on the three-dimensional volume-rendered neurovascular images. The computed tomography angiography images of 56 patients diagnosed with subarachnoid hemorrhage (SAH) were evaluated retrospectively. Two separate researchers, blinded to each other and clinical information of the patients, evaluated the courses of cICA bilaterally. The variations were classified as tortuosity, kinking, and coiling. A total of 112 cICA segments of 56 patients were evaluated. The cICA variations were present in 21.4% of patients and 17.9% of segments. There was tortuosity in 5 (8.9%) patients, kinking in 4 (7.1%) patients, and coiling in 6 (10.7%) patients. Of 41 patients with aneurysmal SAH, there were a cICA variation in 8 (19.5%) patients. A cICA variation was detected in 4 (26.7%) of 15 patients with idiopathic SAH. The cICA variation ratio in SAH patients was concordant with studies performed in different patient groups. Although the ratio was slightly higher in idiopathic SAH patients, there was no statistical significance between the aneurysmal and idiopathic SAH groups. The coiling was more frequent in SAH patients compared to previous studies. The cICA variations tend to be bilateral in SAH patients.

Keywords: internal carotid artery, tortuosity, coiling, kinking, subarachnoid hemorrhage, dolichoarteriopathy

1. Introduction

The internal carotid arteries arise from the common carotid arteries bilaterally. The origins of the common carotid arteries are different on both sides. On the right side, the common carotid artery originates from the brachiocephalic trunk, which is the first branch of the aortic arch. On the other hand, the common carotid artery arises directly from the aortic arch on the left side. The common carotid artery is divided into the external and internal carotid arteries at the level of the superior border of the thyroid cartilage. The internal carotid artery runs vertically upward without major changes in its direction. It lies ventral to the transverse processes of the atlas, axis, and third cervical vertebrae. The internal carotid artery enters the skull via the carotid foramen of the temporal bone. For the first time, Fischer classified the segments of the internal carotid artery based on the angiographic evaluation without considering the direction of blood flow in 1938 (1). Bouthillier and several other authors have proposed different classification systems by numbering the internal carotid artery segments in the direction of blood flow (2). The portion of the internal carotid artery that extends from the carotid bifurcation to the carotid foramen is commonly accepted as the C1 or cervical segment in all proposed classification systems.

The internal carotid artery usually has a straight vertical course along the cervical segment without any branching until it reaches the carotid foramen. The anatomical variations along the cervical segment were reported in 4-66% of cases (3). Tortuosity (S or C-shaped elongation), kinking, and coiling of the artery are the anatomical variations reported previously (4). They may be congenital or acquired in etiology. In the current study, variations of the internal carotid artery along the cervical segment in SAH patients were evaluated based on the three-dimensional volume-rendered neurovascular images by describing the type of variation and reviewing the literature regarding the diagnosis, causes, symptoms, and clinical significances of the variations.

2. Materials and Methods

The study was performed after the approval of Ondokuz Mayıs University clinical research ethics committee with the number of 2014/1364. Fifty-six patients diagnosed with subarachnoid hemorrhage (SAH) were included in this study. The computed tomography angiography images of all patients were evaluated retrospectively.

Imaging data were stored in digital imaging and communications in medicine (DICOM) format and analyzed

*Correspondence: aykanulus@omu.edu.tr

with Osirix 64 MD imaging software [OsiriX Foundation, Geneva, Switzerland]. Three-dimensional reconstructed images of the cervical segment of ICA (cICA) were obtained by using the 3D volume rendering function of the software.

Two separate researchers, blinded to each other and clinical information of the patients, assessed the morphology of cICA. In case of discordance, a third opinion was obtained from another researcher who was blinded to others and clinical information of the patients. Courses of the cICA were evaluated bilaterally for each patient. Regarding the classification of Weibel and Fields, S- or C-shaped elongation with medial or lateral displacement of the elongated segment was defined as tortuosity (Fig. 1). Any sharp angulation less than 90° was defined as kinking (Fig. 2), and the looped course of the artery was defined as coiling (Fig. 3) (4).

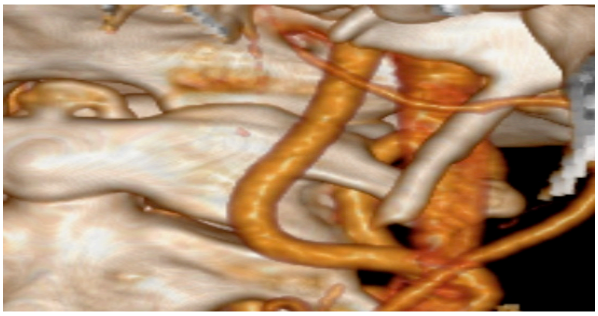

Fig. 1. Tortuosity of the left internal carotid artery cervical segment (3 dimensional reconstruction of computed tomography angiography images)

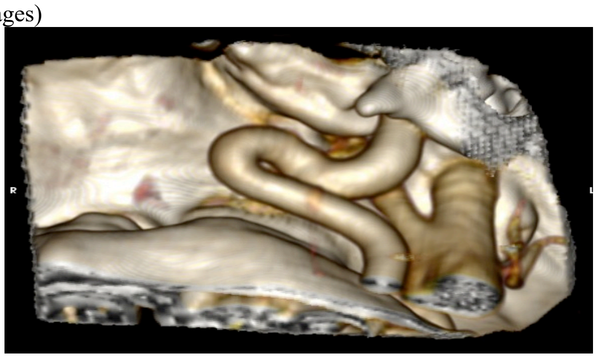

Fig. 2. Kinking of the left internal carotid artery cervical segment (3 dimensional reconstruction of computed tomography angiography images)

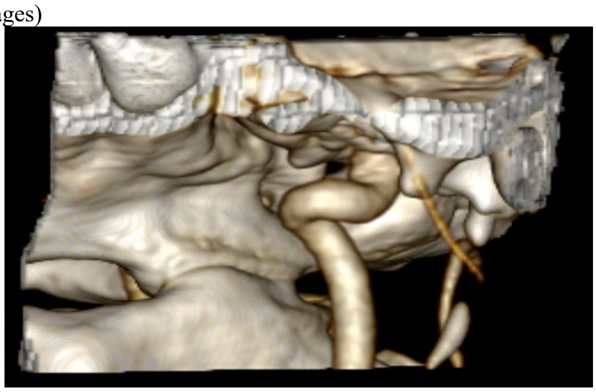

Fig. 3. Coiling of the left internal carotid artery cervical segment (3 dimensional reconstruction of computed tomography angiography images)

Statistical analyses were performed with IBM SPSS version 22.0 for windows. The cICA course variations of the aneurysmal and idiopathic SAH groups were compared by Chi-square test.

3. Results

The computed tomography angiography images of 56 SAH patients (27 male, 29 female) were evaluated. The age range of patients was 36-83 (mean, 57.96±9.61 years). Of 56 patients, the cICA segment variations were present in 12 (21.4%) patients. Male: female ratio was 1.4 (7 (58.3%) male, 5 (41.7%) female). Their mean age was 59.25±7.85. There was tortuosity in 5 (8.9%) patients, kinking in 4 (7.1%) patients, and coiling in 6 (10.7%) patients (Table 1). Variations were bilateral in 8 (66.6%) patients and unilateral in 4 (33.4%) patients. While 5 (62.5%) of 8 patients with bilateral abnormal course had symmetrical variations, the remaining 3 (37.5%) of them had different types of variations on both sides. We found coiling either on the left or right side of all patients with an asymmetrical bilateral variation. Of 4 patients with a unilateral abnormal course, variation was on the right side in 3 patients and on the left side in 1 patient.

A total of 112 cICA segments were evaluated in 56 patients. While the 92 (82.1%) cICA segments had a straight course, there were variations in 20 (17.9%) cICA segments. There was tortuosity in 8 (7.16%) segments, kinking in 6 (5.36%) segments, and coiling in 6 (5.36%) segments. Tortuosity was S-shaped in 1 segment and C-shaped in 7 segments (Table 1). Of the 20 cICA segment variations, 9 (45%) were on the right side, and 11 (55%) were on the left side. Five of the six coilings were on the left side. There was no such dominancy in either tortuosity or kinking.

Table 1. cICA variations in patients and in segments

	In patients (n=56)	In segments (n=112)
cICA variations	12 (21.4%)*	20 (17.9%)
• Tortuosity	5 (8.9%)	8 (7.16%)
• Kinking	4 (7.1%)	6 (5.36%)
• Coiling	6 (10.7%)	6 (5.36%)

*8 bilateral, cICA: cervical segment of internal carotid artery

An aneurysm was detected as a reason for SAH in 41 (73.2%) of 56 patients (aneurysmal SAH). The reason for bleeding could not be found in 15 (26.8%) patients (idiopathic SAH). Of 41 patients with aneurysmal SAH, there were cICA variations in 8 (19.5%) patients. A cICA variation was detected in 4 (26.7%) of 15 patients with idiopathic SAH (Table 2). Regarding the cICA course variations, there was no statistically significant difference between the aneurysmal and idiopathic SAH groups (p= 0.563). Interestingly, all female patients with abnormal course had an aneurysm as a reason of SAH.

Table 2. Subarachnoid hemorrhage types and the internal carotid artery cervical segment variations

SAH type	cICA variations	P value
Aneurysmal	8 (19.5%)	
Idiopathic	4 (26.7%)	>0.05

SAH: Subarachnoid hemorrhage;
cICA:cervical segment of internal carotid artery

4. Discussion

Although the cICA usually has a straight vertical course without any branching from the bifurcation of the common carotid artery to its entrance into the carotid foramen, it may have some variations in its course. These variations usually depend on the elongation of artery. Weibel and Fields classified these variations as tortuosity, kinking, and coiling (4). All of them are results of elongation of the cICA. Displacement of an elongated segment to the medial or lateral side is defined as tortuosity. It may be S- or C- shaped. Less than 90° of angulation of the vessel is defined as kinking. Coiling is the looped course of the artery.

Etiologically, variations of the cICA may be a congenital or acquired condition. Some of them are thought to be of congenital origin as they have been observed in children, and their prevalence showed no increase with age (5). Khasiyev et al. found no correlation between cICA variations and age (6). The cICA develops from the third aortic arch and dorsal aorta. Normally there is a loop between two arteries in the embryonic life stage. The cICA becomes straight with the descent of the large arteries and heart into the mediastinum. Any failure of this process may result in a loop or kink formation (7, 8). But there is no proof supporting this suggestion in the literature. On the other hand, the increased prevalence of cICA variations, especially kinking, with ageing, atherosclerosis and hypertension suggest that it is an acquired condition (9, 10). Buckling is an important factor for tortuosity. Increased lumen pressure, weakened wall and decreased axial tension cause buckling thus tortuosity formation (11). La Barbera et al. suggested that the cICA is a transitional segment between the common carotid artery (an elastic vessel) and intracranial ICA (a muscular vessel) (12). They found metaplastic changes in the tunica media of ICA, which are triggered by a stimulus such as hemodynamic forces, and they suggested that unproportional changes in vessel wall may cause buckling. Fibromuscular dysplasia also may be an etiological factor for a few patients (13).

The cICA variations are generally asymptomatic. They usually remain undiscovered until a symptom occurs due to degenerative changes such as atherosclerosis (14, 15). Riser has noticed the association between carotid kinking and cerebrovascular insufficiency for the first time (16). Although several studies suggest poor correlation between cICA variations and atheromatous plaque formation or cerebrovascular stroke, the cICA variations are thought to be an important predisposing factor for cerebrovascular insufficiency even in the absence of atherosclerosis (14, 17-19). Kinking with less than 60° of angle increases cerebral infarction risk (20).

The cICA variations presenting as a pulsatile mass may cause an abnormal sensation in the throat (21). They are also reported as a possible cause of hypoglossal nerve palsy, hemilingual spasm, and snoring (22-24).

Otolaryngologists have published many papers about the importance of cICA variations, because cICA injuries may cause fatal hemorrhages during tonsillectomy (25, 26). The cICA may be injured during the neck dissection phase of any surgical intervention performed on the neck, such as tonsillectomy, adenoidectomy, peritonsillar abscess drainage (27). The injury risk increases if the variations are not realized preoperatively or the surgeon is unaware of the probability.

Neurosurgical interventions such as upper cervical discectomy, instrumentation of odontoid fractures, and carotid endarterectomy need detailed anatomy knowledge of the cICA variations as well as the normal anatomy.

The cICA variations have a significant impact on endovascular interventions, either for imaging or treatment of cerebral vascular pathologies. Carotid stenosis is treated by carotid endarterectomy or stenting; cICA variations may complicate both. A coiling or kinking at the distal part of stenosis may cause technical failure of carotid stenting, especially during delivery of a distal protection device, which is used to prevent embolism (28-32).

The cICA variations may also complicate the endovascular interventions by preventing access to the intracranial vascular pathologies such as aneurysms and arteriovenous malformations (33).

The prevalence of cICA variations is 4-66% in literature (3). We found cICA variations in 21.4% of patients and 17.9% of cICA segments, in line with the literature. Several studies report female or male predominancy, or no sexual differences. Even though there is a tendency for a female predominance of cICA variations in literature, our male: female ratio (=1.4) is concordant with Koskas et al. (3, 6, 15, 34). Bilateral variations were reported as 24-40% in previous studies (9, 15, 35). We found that 66.6% of the cICA variations were bilateral.

There are different prevalence ratios of cICA variations in the literature regarding Weibel and Fields classification. Kinking is the most frequent, and coiling is the least frequently reported variation (3, 17). But these studies are usually performed on highly selected patients with neurologic or cardiovascular symptoms. Their result cannot be attributed to the normal population. Different prevalence rates may be explained by the non-randomized selection of the study population, different diagnostic techniques, or some nuances in the classification of cICA variations. Paulsen et al. reported that the curved course of the cICA was more frequent than kinking and coiling in their cadaver study, which was performed on head and neck preparations randomly obtained from the anatomy department (3). Coiling was the most frequent variation (10.7 % of the patients) in our study. The coiling ratio was reported as 1.4-4% in previous studies (3, 5, 15, 17, 34-36). In the present study, the coiling ratio of 10.7% was more than two times higher than these values. The prevalence of coiling is clearly higher in SAH patients.

The relationship between some vascular pathologies and cICA course variations is a known issue, such as cICA aneurysms and dissections (37, 38). Hamada et al. reported a relationship between AVM nidus size and severity of tortuosity (39). The most important limitation of the present study is the highly selective patient population, which all have SAH. But this limitation provides us with additional information about cICA variations in patients with SAH. The cICA variation ratio in SAH patients was 21.4% in the present study, which was concordant with previous studies performed on normal or selective populations with pathologies other than SAH. This ratio was slightly lower (19.5%) in aneurysmal SAH patients and slightly higher (26.7%) in idiopathic SAH patients. There was no statistical significance when we compared the aneurysmal and idiopathic SAH groups regarding the cICA course variation. In contrast to the present study, the prevalence of convolution and looping in patients with aneurysmal SAH was higher than in idiopathic SAH, according to Nikiforov et al. (40).

The cICA variations may cause fatal vascular injury in surgical interventions performed on the neck, such as tonsillectomy, adenoidectomy, and upper cervical discectomy. Their prevalence in SAH patients is concordant with the normal population. But the coiling ratio in SAH patients reported here is one of the highest in the literature. There is no difference between aneurysmal SAH patients and idiopathic SAH patients regarding the cICA variations. A prospective randomized study performed on more patients may give more objective results.

Conflict of interest
The authors declare that there is no conflict of interest.

Funding
No funding was used for the study.

Acknowledgments
None to declare.

References

1. Fischer E. Die Lageabweichungen der vorderen hirnarterie im gefassbild. Zentralbl Neurochir. 1938;3:300-13.
2. Bouthillier A, van Loveren HR,Keller JT. Segments of the internal carotid artery: a new classification. Neurosurgery. 1996;38(3):425-32; discussion 32-3.
3. Paulsen F, Tillmann B, Christofides C, Richter W,Koebke J. Curving and looping of the internal carotid artery in relation to the pharynx: frequency, embryology and clinical implications. J Anat. 2000;197 Pt 3:373-81.
4. Weibel J,Fields WS. Tortuosity, Coiling, and Kinking of the Internal Carotid Artery. I. Etiology and Radiographic Anatomy. Neurology. 1965;15:7-18.
5. Beigelman R, Izaguirre AM, Robles M, Grana DR, Ambrosio G,Milei J. Are kinking and coiling of carotid artery congenital or acquired? Angiology. 2010;61(1):107-12.
6. Khasiyev F, Rundek T, Di Tullio MR, Wright CB, Sacco RL, Elkind MSV, et al. Systemic Arterial Correlates of Cervical Carotid Artery Tortuosity : The Northern Manhattan Study. Clin Neuroradiol. 2021.
7. Cairney J. Tortuosity of the Cervical Segment of the Internal Carotid Artery. J Anat. 1924;59(Pt 1):87-96.
8. Metz H, Murray-Leslie RM, Bannister RG, Bull JW,Marshall J. Kinking of the internal carotid artery. Lancet. 1961;1(7174):424-6.
9. Del Corso L, Moruzzo D, Conte B, Agelli M, Romanelli AM, Pastine F, et al. Tortuosity, kinking, and coiling of the carotid artery: expression of atherosclerosis or aging? Angiology. 1998;49(5):361-71.
10. Pancera P, Ribul M, Presciuttini B,Lechi A. Prevalence of carotid artery kinking in 590 consecutive subjects evaluated by Echocolordoppler. Is there a correlation with arterial hypertension? J Intern Med. 2000;248(1):7-12.
11. Han HC. Twisted blood vessels: symptoms, etiology and biomechanical mechanisms. J Vasc Res. 2012;49(3):185-97.
12. La Barbera G, La Marca G, Martino A, Lo Verde R, Valentino F, Lipari D, et al. Kinking, coiling, and tortuosity of extracranial internal carotid artery: is it the effect of a metaplasia? Surg Radiol Anat. 2006;28(6):573-80.
13. Danza R, Baldizan J,Navarro T. Surgery of carotid kinking and fibromuscular dysplasia. J Cardiovasc Surg (Torino). 1983;24(6):628-33.
14. Liu J, Jia XJ, Wang YJ, Zhang M, Zhang T,Zhou HD. Digital subtraction angiography imaging characteristics of patients with extra-intracranial atherosclerosis and its relationship to stroke. Cell Biochem Biophys. 2014;69(3):599-604.
15. Sacco S, Totaro R, Baldassarre M,Carolei A. Morphological variations of the internal carotid artery: Prevalence, characteristics and association with cerebrovascular disease. Int J Angiol. 2007;16(2):59-61.
16. Riser M, Geraud J, Ducoudray J,Ribaut L. Dolichocarotide interne avec syndrome vertigineux. Rev Neurol (Paris). 1951;85(2):145-7.
17. Togay-Isikay C, Kim J, Betterman K, Andrews C, Meads D, Tesh P, et al. Carotid artery tortuosity, kinking, coiling: stroke risk factor, marker, or curiosity? Acta Neurol Belg. 2005;105(2):68-72.
18. Vannix RS, Joergenson EJ,Carter R. Kinking of the internal carotid artery. Clinical significance and surgical management. Am J Surg. 1977;134(1):82-9.
19. Khasiyev F,Gutierrez J. Cervical Carotid Artery Dolichoectasia as a Marker of Increased Vascular Risk. J Neuroimaging. 2021;31(2):251-60.
20. Kaplan ML,Bontsevich DN. Effect of the form of pathological tortuosity of the internal carotid artery on cerebral haemodynamics. Angiol Sosud Khir. 2013;19(3):102-6.
21. Hosokawa S,Mineta H. Tortuous internal carotid artery presenting as a pharyngeal mass. J Laryngol Otol.

2010;124(9):1033-6.

22. Eyibilen A, Baykara M,Ozbay AS. A possible cause of snoring: bilateral tortuosity of the internal carotid artery. Kulak Burun Bogaz Ihtis Derg. 2008;18(4):250-2.

23. Heckmann JG, Marthol H, Bickel A, Dorfler A,Neundorfer B. Hemilingual spasm associated with tortuosity of the extracranial internal carotid artery. Cerebrovasc Dis. 2005;20(3):208-10.

24. Scotti G, Melancon D,Olivier A. Hypoglossal paralysis due to compression by a tortuous internal carotid artery in the neck. Neuroradiology. 1978;14(5):263-5.

25. Becker C, Ridder GJ,Pfeiffer J. The clinical impact of aberrant internal carotid arteries in children. Int J Pediatr Otorhinolaryngol. 2014;78(7):1123-7.

26. Jackson JL. Tortuosity of the Internal Carotid Artery and Its Relation to Tonsillectomy. Can Med Assoc J. 1933;29(5):475-9.

27. Kudva A, Dhara V, Patil BR,Sankaran M. Caution with carotids: A necessary cognizance. Oral Oncol. 2021;121:105392.

28. Ding D, Starke R,Evans A. E-050 Navigation of a Distal Cerebral Embolic Protection Device through Significant Vascular Tortuosity with a Novel Rapid Exchange Catheter System during Carotid Artery Stenting. J Neurointerv Surg. 2014;6 Suppl 1:A61.

29. Van Damme H, Gillain D, Desiron Q, Detry O, Albert A,Limet R. Kinking of the internal carotid artery: clinical significance and surgical management. Acta Chir Belg. 1996;96(1):15-22.

30. Wang Q, Liu C, Yan B, Fan X, Zhang M, Li Y, et al. Correlation of extracranial internal carotid artery tortuosity index and intraprocedural complications during carotid artery stenting. Eur Neurol. 2012;68(2):65-72.

31. Wyers MC, Powell RJ, Fillinger MF, Nolan BW,Cronenwett JL. The value of 3D-CT angiographic assessment prior to carotid stenting. J Vasc Surg. 2009;49(3):614-22.

32. Jeong DE, Kim JW, Kim BM, Hwang W,Kim DJ. Impact of Balloon-Guiding Catheter Location on Recanalization in Patients with Acute Stroke Treated by Mechanical Thrombectomy. AJNR Am J Neuroradiol. 2019;40(5):840-4.

33. Peeling L,Fiorella D. Balloon-assisted guide catheter positioning to overcome extreme cervical carotid tortuosity: technique and case experience. J Neurointerv Surg. 2014;6(2):129-33.

34. Koskas F, Bahnini A, Walden R,Kieffer E. Stenotic coiling and kinking of the internal carotid artery. Ann Vasc Surg. 1993;7(6):530-40.

35. Pellegrino L, Prencipe G,Vairo F. Dolicho-arteriopathies (kinking, coiling, tortuoosity) of the carotid arteries: study by color Doppler ultrasonography. Minerva Cardioangiol. 1998;46(3):69-76.

36. Poulias GE, Skoutas B, Doundoulakis N, Haddad H, Karkanias G,Lyberiadis D. Kinking and coiling of internal carotid artery with and without associated stenosis. Surgical considerations and long-term follow-up. Panminerva Med. 1996;38(1):22-7.

37. Petro GR, Witwer GA, Cacayorin ED, Hodge CJ, Bredenberg CE, Jastremski MS, et al. Spontaneous dissection of the cervical internal carotid artery: correlation of arteriography, CT, and pathology. AJR Am J Roentgenol. 1987;148(2):393-8.

38. Saba L, Argiolas GM, Sumer S, Siotto P, Raz E, Sanfilippo R, et al. Association between internal carotid artery dissection and arterial tortuosity. Neuroradiology. 2015;57(2):149-53.

39. Hamada J, Kai Y, Morioka M, Kaku T, Korematsu K,Ushio Y. Tortuosity of the Cervical Segment of the Internal Carotid Artery in AVM Patients. Interv Neuroradiol. 1997;3 Suppl 2:133-6.

40. Nikiforov BM,Rudenko I. Tortuosity of the internal carotid artery. Zh Nevropatol Psikhiatr Im S S Korsakova. 1981;81(7):977-80.