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Original articles

Carotid artery tortuosity, kinking, coiling : stroke risk factor, marker, or curiosity ?

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Abstract

Although abnormalities in course and geometry (tortuosity, kinking, and coiling) of the internal carotid arteries (ICA) are commonly identified, their etiology and relationship with stroke and stroke risk factors remain unclear. This study assessed the clinical and ultrasonographic features of the patients with abnormalities in course and geometry of the ICA.

Carotid color duplex ultrasound studies of 345 consecutive patients referred to the Neuroultrasound Lab were prospectively evaluated. Abnormalities in direction and course of the ICA were classified according to the criteria of Weibel-Fields and Metz modified by the authors. Kinking was categorized as mild (> 60°), moderate (30°-60°), and severe (< 30°).

Carotid abnormalities (CA) were found in 85/345 (24.6%), 60/85 (70.6%) were female. More CA were seen in females older than 60 y/o ($p < 0.001$), but there was no gender difference in patients 60 y/o or younger. CA were bilateral in 41 patients (48%), but in those with unilateral CA, most were on the left. The most common CA was kinking (71 arteries, 56%), followed by tortuosity (48 arteries, 38%), and coiling (7 arteries, 6%). None of the atherosclerotic vascular diseases or risk factors was associated with CA. Mild atheromatous plaques predominated in patients with CA, but moderate and large plaques were more common in the others ($p = 0.001$). Maximal systolic velocity at the level of CA was higher in patients with kinking or coiling compared with tortuosity ($p = 0.001$). Lumen diameter at the level of CA was inversely correlated to the severity of CA ($p < 0.001$). However, carotid stenosis was equally present in all groups.

This study suggests that CA have no clear importance as a stroke risk factor or marker of atherosclerotic vascular disease. Our results suggest that CA do not develop as a consequence of vascular risk factors or atherosclerotic lesions, and they are not related to ischemic stroke, TIA or the presence of carotid stenosis. In women, CA was related with advanced age. It appears that CA frequently identified by color duplex sonography are more of curiosity than a clinically significant finding.

Key words : Carotid artery ; tortuosity ; kinking ; coiling ; stroke.

Introduction

Abnormalities in course and geometry of the internal carotid arteries (ICA) are commonly identified in ultrasound and angiography studies, and their classification as tortuosity, kinking and coiling was first introduced in 1965 by Weibel and Fields (Weibel and Fields, 1965). According to this classification, tortuosity is an S- or C-shaped elongation or undulation in the course of the internal carotid artery (ICA). Coiling was defined as elongation or redundancy of the ICA resulting in an exaggerated S-shaped curve or in a circular configuration. Kinking, the most frequently reported type of carotid abnormalities (CA), was described as an acute angulation of the ICA and classified according to the severity of the angle between the two segments forming the kink (Metz *et al.*, 1961). Macchi et al reported that carotid kinkings were present in 38% of the individuals with no history of atherosclerotic disease, diabetes or hypertension (Macchi *et al.*, 1997). They proposed to consider the tortuosities with a velocimetric increase more than 60% as kinkings.

Carotid abnormalities were seen in a wide ranged frequency from 10% to 43% in the studies performed by arteriography (Metz *et al.*, 1961 ; Weibel and Fields, 1965 ; Koskas *et al.*, 1994). The introduction of carotid duplex ultrasound has made possible the noninvasive evaluation of both morphology and flow characteristics of the carotid arteries and revealed the frequency of CA. Del Corso et al reported that CA were present in more than half of the patients with cardiovascular or cerebral ischemic symptoms using ultrasound (Del Corso *et al.*, 1998).

Carotid abnormalities are rarely observed in children and youthful, and explained by congenital etiology in these cases. Older individuals were reported to be more commonly affected by CA (Weibel and Fields, 1965 ; Del Corso *et al.*, 1998). Although CA are considered mainly linked with aging and vascular risk factors resulting in progressing atherosclerosis, there is no clear evidence

Table 1

Modified criteria of Weibel-Fields and Metz

	Modified criteria of Weibel-Fields and Metz
Tortuosity :	S- or C-shaped elongation or undulation in the course of the ICA.
Mild kinking :	Acute angulation of the ICA with an angle between the two segments forming the kink measured ≥ 60°.
Moderate kinking :	Acute angulation of the ICA with an angle between the two segments forming the kink measured 30°-60°.
Severe kinking :	Acute angulation of the ICA with an angle between the two segments forming the kink measured < 30°.
Coiling :	Elongation or redundancy of the ICA resulting in an exaggerated S-shaped curve or a circular configuration. Angulations of more than two subsequent segments of the ICA were included into this group.

showing this association (Desai and Toole, 1975). The clinical importance of CA and their role in ischemic stroke also still remains controversial. The aim of this study was to analyze the features and clinical significance of CA detected in course and geometry of the ICA by ultrasound.

Methods and materials

Carotid color duplex ultrasound studies of 345 consecutive patients referred to the Neuro-ultrasound Lab between the dates of May 1, 2002 and October 1, 2002 were evaluated prospectively. The most common reason of ultrasound studies was ischemic stroke or transient ischemic attacks (TIA), followed by carotid bruit, follow-up for atherosclerotic carotid disease, syncope, coronary artery disease, visual changes, and other conditions such as vertigo, peripheral artery disease, preoperative evaluation, unexplained mental status changes, and obscure neurological symptoms. The carotid color duplex ultrasound examinations were performed by three ultrasonographers (Carol Andrews, RVT ; Dana Meads, RVT ; Paul Tesh, RVT) and recorded for subsequent review by the physicians. The subjects with incomplete ultrasound studies due to short conformation of the neck or high bifurcation of the common carotid artery were not included.

The clinical features [age, gender, the presence of any vascular risk factor such as hypertension (systolic/diastolic blood pressure > 140/90 mmHg or being on antihypertensive treatment), diabetes (fasting blood glucose > 110 mg/dl or being on antidiabetic treatment), hyperlipidemia (total cholesterol > 200 mg/dl or LDL > 125 mg/dl), and cigarette smoking, the presence of other atherosclerotic diseases such as ischemic heart disease (previous myocardial infarction, stable/unstable angina or a history of coronary angioplasty or surgery), peripheral vascular disease (claudication or a history of peripheral vascular surgery), and history of ischemic stroke or TIA], the reason of ultrasound examination, and abnormal findings in morphology and flow characteristics of the ICA by ultrasound studies were recorded in detailed.

Abnormalities in direction and course of the ICA were classified according to the criteria of Weibel-Fields and Metz modified by the authors (Table 1) (Metz *et al.*, 1961 ; Weibel and Fields, 1965). The lumen diameter at the origin of the ICA, maximal systolic (MSV) and end-diastolic blood flow velocities (DV) at this level, at the level of CA and at the outlet of CA, the morphology of the CA and its distance from the ICA origin were recorded. The presence of atheromatous plaques and their size (plaques measured between 1.1-2.0 mm were defined as mild, plaques between 2.1-3.0 were defined as moderate, and plaques larger than 3 mm were defined as large) were also assessed.

We used chi-square test and multiple logistic regression analysis to determine the association of CA with age, sex, vascular risk factors, and carotid plaques. Differences were considered statistically significant at a p value of less than 0.05. Friedman and Wilcoxon tests were used to compare the blood flow velocities and lumen diameters within the groups (tortuosity, kinking and coiling), Kruskal-Wallis, Mann-Whitney U and Student t tests were used to compare these parameters between the groups. Bonferroni correction was used to determine significant p values.

Results

Carotid abnormalities were found in 85/345 (24.6%), and 60/85 (70.6%) were female. More CA were seen in females older than 60 years of age ($p < 0.001$), but there was no gender difference in patients 60 years of age or younger. The mean age of the patients with CA (67 ± 13) was not significantly different from those without CA (64 ± 15). CA were bilateral in 41 patients (48%), but in those with unilateral CA, most were on the left (68%). CA were detected in 126/690 arteries (18%). The most common CA was kinking (71 arteries, 56%), followed by tortuosity (48 arteries, 38%), and coiling (7 arteries, 6%). Kinking was usually mild (mild = 76%, moderate = 17%, severe = 7%).

Diabetes, coronary artery disease, and ischemic stroke were more frequent in patients without CA than the others with CA ($p = 0.004$, $p = 0.046$ and

Table 2

Gender, age, atherosclerotic vascular diseases and risk factors in the patient groups with and without carotid abnormalities

	CA (-)	CA (+)	Total
Female *n (%)*	134 (51.5%)	60 (70.6%)	194 (56.2%)
Male *n (%)*	126 (48.5%)	25 (29.4%)	151 (43.8%)
Age ≤ 60 *n (%)*	102 (39.2%)	30 (35.3%)	132 (38.3%)
Age > 60 *n (%)*	158 (60.8%)	55 (64.7%)	213 (61.7%)
Hypertension *n (%)*	199 (76.5%)	63 (74.1%)	262 (75.9%)
Diabetes *n (%)*	92 (35.4%)	16 (18.8%)	108 (31.3%)
Hyperlipidemia *n (%)*	138 (53.1%)	39 (45.9%)	177 (51.3%)
Smoking *n (%)*	91 (35%)	29 (34.1%)	120 (34.8%)
Coronary artery disease *n (%)*	108 (41.5%)	25 (29.4%)	133 (38.6%)
Peripheral artery disease *n (%)*	24 (9.2%)	6 (7.1%)	30 (8.7%)
TIA *n (%)*	22 (8.5%)	6 (7.1%)	28 (8.1%)
Ischemic stroke *n (%)*	64 (24.6%)	10 (11.8%)	74 (21.4%)
Carotid stenosis *n (%)*	52 (20%)	10 (11.8%)	62 (18%)

CA : Carotid abnormality, TIA : Transient ischemic attack.

Table 3

Results of the multiple logistic regression analysis

Presence of CA	B	S.E	Significance	OR
Gender (♀)	0.804	0.273	0.003	2.233
Diabetes (-)*	0.844	0.312	0.007	2.325
Ischemic stroke (-)**	0.827	0.373	0.027	2.286

CA : Carotid abnormality, * : Patients with no diabetes, ** : Patients with no ischemic stroke.

$p = 0.012$, respectively), while hypertension, hyperlipidemia, smoking, peripheral artery disease, TIA, and carotid stenosis were equally present in both groups (Table 2). Multiple logistic regression analysis showed that female gender was significantly associated with CA, while diabetes and ischemic stroke were inversely related to CA (Table 3).

The mean ± SD distance of CA from the origin of the ICA was 3.3 ± 1.1 cm. The lumen diameter at the origin of the ICA was larger in patients with CA (5.99 ± 1.7 mm) than those without CA (5.08 ± 2.0 mm) ($p < 0.001$). Lumen diameter at the level of CA was inversely correlated to the severity of CA ($p < 0.001$). MSV at the level of kinkings and coilings were higher than that at the level tortuosities, but MSV in the origin of the ICA and at the outlet of CA were not significantly different among three groups (Table 4). In the arteries with kinking, MSV at the level of CA was higher than those in the origin of the ICA and at the outlet of CA ($p < 0.001$).

Mild atheromatous plaques predominated in patients with CA, while moderate and large plaques were more common in the others ($p = 0.002$ and $p = 0.001$, respectively). Carotid stenosis (≥ 50%) was equally present in both groups. Advanced age (> 60 y/o), male gender, hyperlipidemia, and smoking were associated with the presence of carotid plaques ($p < 0.001$, OR : 6.66 ; $p < 0.001$, OR : 4.09 ; $p = 0.001$, OR : 2.74 ; and $p = 0.03$, OR : 2.09, respectively).

Discussion

A wide range of CA from 10% to 43% was reported based on the studies performed with angiography (Metz *et al.*, 1961 ; Weibel and Fields, 1965 ; Koskas *et al.*, 1994). As carotid color duplex ultrasound is an inexpensive and non-invasive examination, and provides useful information for the morphological configuration and hemodynamic status of the carotid arteries, it replaced angiography in evaluating CA. According to the studies performed with carotid duplex ultrasound, the prevalence of CA ranged from 28% to 56% (Macchi *et al.*, 1997 ; Del Corso *et al.*, 1998 ; Pancera *et al.*, 1998 ; Pellegrino *et al.*, 1998 ; Pancera *et al.*, 2000). Our study showed that about one fourth of the patients referred for the carotid duplex ultrasound have CA. A similar prevalence of CA (25.9%) was reported by Pellegrino, while Del Corso reported a higher frequency (58%) in their study population (Del Corso *et al.*, 1998 ; Pellegrino *et al.*, 1998). As different from ours, the abnormalities in the external and common carotid arteries as well as in the ICA were included in these two studies. However, 94-96% of CA were localized at the level of the ICA (Del Corso *et al.*, 1998 ; Pellegrino *et al.*, 1998). The wide range of prevalence of CA can be explained by the use of different methods and diagnostic tools, and the selection of different study groups.

Table 4

Blood flow velocities and lumen diameters in the internal carotid arteries with tortuosity, kinking and coiling

	P		Median	Minimum	Maximum
MSV^1 (cm/s)	$p = 0.994$	Tortuosity	76.0	24	205
		Kinking	77.5	41	184
		Coiling	81.0	57	93
MSV^2 (cm/s)	$p = 0.001$*	Tortuosity	84.5	48	114
		Kinking	103.0	48	296
		Coiling	120.0	99	121
MSV^3 (cm/s)	$p = 0.845$	Tortuosity	88.0	52	208
		Kinking	87.5	42	220
		Coiling	94.0	56	170
LD^1	$p = 0.808$	Tortuosity	6.45	3.2	10.0
		Kinking	6.30	1.9	9.6
		Coiling	6.08	4.3	6.9
LD^2	$p < 0.001$*	Tortuosity	4.55	4.2	5.5
		Kinking	3.75	2.4	5.2
		Coiling	2.80	2.5	3.1

MSV^1 : Maximal systolic velocity in the origin of the internal carotid artery, MSV^2 : Maximal systolic velocity at the level of carotid abnormality, MSV^3 : Maximal systolic velocity in the outlet of carotid abnormality, LD1 : Lumen diameter in the origin of the ICA, LD2 : Lumen diameter at the level of carotid abnormality, * : statistically significant.

In this study, kinking was significantly more frequent than tortuosity and coiling, in agreement with the previous studies (Weibel and Fields, 1965 ; Del Corso *et al.*, 1998 ; Pellegrino *et al.*, 1998). Most of the CA were located at about 3 cm beyond the carotid bifurcation, which is similar to the results of Weibel and Fields and the others (Weibel and Fields, 1965 ; Macchi *et al.*, 1997). The common location of CA at this level enables carotid duplex ultrasound to visualize them easily except for those cases with high bifurcation of the common carotid artery and short conformation of the neck. This also supports that the carotid duplex ultrasound is a suitable tool to evaluate abnormalities in the carotid arteries. We observed a frequent presence of bilateral CA (48%) and predominance for the left in cases with unilateral CA, which was compatible with the previous studies (Macchi *et al.*, 1997 ; Pellegrino *et al.*, 1998).

Our results do not agree with the studies showing a greater prevalence of CA in men (Weibel and Fields, 1965 ; Koskas *et al.*, 1994), and in the elderly (Del Corso *et al.*, 1998 ; Pancera *et al.*, 1998 ; Pancera *et al.*, 2000). In this study, elderly women (> 60 y/o) were more frequently affected by CA, but both sexes were equally affected among the patients under the age of 60. In opposite to our results showing that CA was related to advanced age in women, Pellegrino et al showed decreasing frequency of CA in women after the age of 70 (Pellegrino *et al.*, 1998). Other authors reported a higher frequency of CA in women independent of the age (Macchi *et al.*, 1997 ; Del Corso *et al.*, 1998). The lack of correlation with age in men may support the congenital etiology of CA, which seems less likely in women. In the embryo, the ICA is formed from the third aortic arch and from the dorsal aorta ; hence it is normally kinked. As the heart recedes into the thorax, the vessel is stretched and the kink eliminated. If the embryological state persists, it produces different kinds of undulations, loops, and kinks (Desai and Toole, 1975). This developmental abnormality explains the presence of CA in infants and even in fetuses (Metz *et al.*, 1961).

It is still controversial whether CA are related to vascular risk factors, such as hypertension, hyperlipidemia and diabetes, atherosclerotic diseases and ischemic stroke. Some of the previous studies showed an association between CA and vascular risk factors or carotid atherosclerosis (Del Corso *et al.*, 1998), while most of them did not (Pellegrino and Prencipe, 1998 ; Prencipe *et al.*, 2000 ; Pellegrino *et al.*, 2002). Some authors suggested a possible relationship between kinking of the carotid artery and hypertension or TIA (Prencipe *et al.*, 1998 ; Pancera *et al.*, 2000). On the other hand, kinkings without atheromatous plaques, though rather frequent, are usually not considered as a cause of stroke (Koskas *et al.*, 1993 ; Ktenidis *et al.*, 1994 ; Prencipe *et al.*, 1998 ; Pancera *et al.*, 2000).

Based on the results of this study, we can speculate that CA do not develop as a consequence of vascular risk factors or atherosclerotic lesions, and they are not associated with a history of cerebral or cardiac ischemic symptoms or the presence of carotid stenosis. These results are consistent with those reported by Pellegrino *et al.* showing that cardiovascular risk factors and atherosclerotic lesions were equally present in both groups with or without CA (Pellegrino and Prencipe, 1998). Moreover,

CA seem to be protective for moderate to large atheromatous plaques in the ICA. Pellegrino et al also suggested that CA seem to prevent plaque formation in the presence of vascular risk factors or hypertension alone (Pellegrino and Prencipe, 1998).

Some correlation among the lumen diameter, atherosclerosis, and kinkings were demonstrated previously (Macchi *et al.*, 1993). Although larger lumen diameters at the origin of the ICA were obtained in cases with CA in our study, plaque severity was less prominent in these cases. Lack of correlation between the lumen diameter and carotid plaques favors the embryogenic hypothesis in the pathogenesis of CA.

We think that relatively higher MSV and lower lumen diameters at the level of kinkings and coilings do not have a clinical significance, because these findings were not associated with atheromatous plaques or carotid stenosis. Additionally, angle correction while examining these sites of the arteries may not always be optimum and cause overestimation of the flow velocities. One may propose that the flow disturbance caused by CA may play a role in the development of TIA, but no significant difference was found between the patients with CA and the others, in terms of TIA.

This study suggests that although CA are seen frequently in clinical practice, they have no clear importance as a risk factor of ischemic stroke or a marker of carotid or systemic atherosclerosis. It appears that CA identified on color duplex ultrasound are more of a curiosity than a clinically significant finding. Furthermore, CA may even prevent moderate to severe plaque formation in the carotid arteries. The hypothesis that CA may also prevent ischemic stroke should be assessed in a larger patient population prospectively. In conclusion, given the high frequency of CA and present results, CA could not be considered completely pathological.

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