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Prevalence of internal carotid artery morphological variations and its association with cerebrovascular ischemic stroke (hospital-based study)

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Abstract

Background and objectives: Morphological variations (MV) in the course of the internal carotid artery (ICA) are commonly identified. Their prevalence and relationship with ischemic stroke (IS) remain unclear. The present study attempted to estimate the prevalence and pattern of MV of ICA among Egyptian patients and to detect whether these MV associated with increased risk of IS or not.

Methods: Out of the recruited 550 acute ischemic stroke patients, 102 met the inclusion and exclusion criteria and were included in our study. Each patient was subjected to detailed history including risk factors and clinical assessment using the National Institute of Health Stroke Scale, mRS, and extracranial duplex ultrasound (US) assessment.

Results: Eleven patients out of 102 (10.8%) showed MV in their ICA course, 6 of them were women and 5 were men. These MV were unilateral in 90.9% (10/11) of cases and more in the left ICA (72.7%), while one case (9.1%) showed MV of both ICA. The commonest pattern of MV was tortuosity in 7 cases (63.6%) and kinking in 4 cases (36.4%). The history of previous IS and TIA was recorded in 9.1% of patients with MV in ICA for each group, while the history of IS was recorded in 13.2% of patients without MV and TIA in 4.3% patients without MV in ICA. There were no statistically significant differences between both groups.

Conclusion: The prevalence of MV in the present study is 10.8%. MV are more frequent in women and older patients and are not associated with an increased risk of ischemic stroke.

Keywords: Pattern, Morphologic, Variations, ICA, Ischemic, Stroke, Duplex

Introduction

In Egypt, there is a high crude prevalence rate of ischemic stroke (IS): 936/100,000 and 922/100,000 in Assiut and Qena governorates, respectively [1, 2], compared to prevalence rates in other Arabic counties [3]. Morphological variations (MV) of the internal carotid artery (ICA) are often classified into tortuosity, kinking, and coiling [4]. According to the previous

classification, tortuosity is an S- or C-shaped elongation or undulation in the course of 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 ICA and classified according to the severity of the angle between the two segments forming the kink [5]. The etiology of ICA MV can be either congenital or acquired. Congenital variations are observed in both youth adults and children. Acquired could be due to atheroma,

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aging, and/or hypertension [6]. The clinical significance of MV in ICA is not well studied; however, a tortuous artery may increase the probability of vessel spasm [6], and some authors postulated that MV are associated with a higher risk of IS [7]. However, Radak et al. stated that IS accident occurs in about 11–33% of these cases [8]. The prevalence of ICA MV in IS patients ranged from 4 to 66% [7, 9–11].

Despite their common occurrence, conclusive evidence about their prevalence and relationship with the IS is still lacking [6].

Up to our knowledge, the prevalence of ICA MV, their characteristics, and its impact on IS are not well studied among Egyptian patients. The aim of the study was to estimate the prevalence and pattern of morphological variations of the ICA among IS patients and to study if there is a link between these MV and the risk of IS occurrence or not.

Main text

Patients and methods

Our hospital-based study was conducted in the Neurology Department, Assuit University hospitals, during the period from May 1, 2018, to April 30, 2019.

One hundred two patients out of 550 recruited patients diagnosed with acute ischemic stroke (Fig. 1) fulfilled the following inclusion criteria: age > 18 years, acute ischemic stroke, and transient ischemic attack in anterior circulation presented within 48 h diagnosed according to WHO diagnostic criteria. Exclusion criteria were patients with carotid stenosis due to atherosclerosis or dissection; patients with known vasculitis or discovered to have after duplex examination; patients with IHD, AF, and cardiomyopathy; patients hemodynamically unstable; patients difficult to be examined with duplex ultrasound; and refusal to participate.

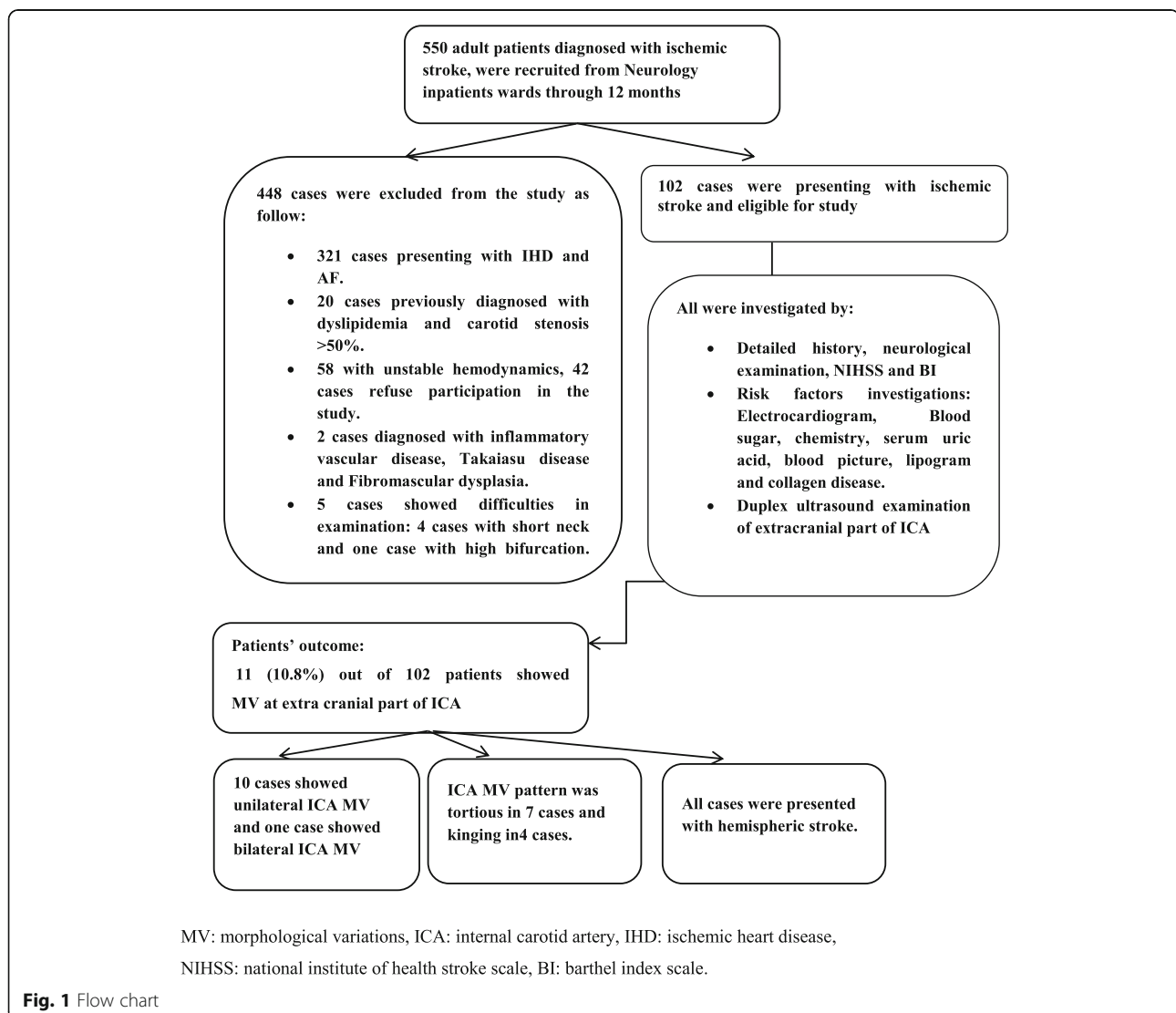


Fig. 1 Flow chart

All patients underwent full detailed history, general, and neurologic examination, and their stroke severity was assessed on admission using the National Institutes of Health Stroke Scale (NIHSS) and modified Rankin scale (mRS). All patients had computerized tomography (CT brain) using non-enhanced thin sections helical 16 multidetector CT (GE optima CT scanners made in Chicago, USA), and some patients with normal CT brain had additional magnetic resonance imaging (MRI) of the brain to confirm the diagnosis of stroke using a 1.5-T scanner (Achieva, Philips made in Amsterdam, Netherlands). Routine laboratory investigations and collagen profile screening were performed for the detection of IS risk factors. ECG and Echo were done to all patients to exclude the cardioembolic source of stroke.

Duplex ultrasound examination took place in the Neurovascular Ultrasound Laboratory at the Neurology Department in cooperation with ultrasound outpatients' clinic at the Department of Vascular and Endovascular Surgery, Assiut University Hospitals. All measurements were done using a high-resolution color duplex Philips EnVisor C and Philips HD5 (Philips Medical Systems, Nederland B.V.) with L 3–12 MHz linear transducer probe. The examination was performed by two experienced sonographers. The extracranial vessels were examined using an examination protocol, and atherosclerotic changes were interpreted according to the criteria published by the Society of Radiologists in Ultrasound [12].

In our study, we defined abnormal shape and course of the extracranial vessels according to the modified Weibel and Fields classification [13]. The angle of the kink is measured between 2 lines parallel to the vessel's wall proximal and distal to the most extreme angulation presented in. The kink was considered mild if the angle is more than 60° and moderate when the angle is between 30 and 60°. The kink is considered severe when the angle is less than 30°.

Statistical analysis

The data were analyzed using SPSS 16.0 software. Qualitative data were described in frequency using percentage (%). Continuous variables were expressed in mean \pm SD. Comparative statistical analysis between variables of both groups, patients with versus without MV of ICA, was done using the chi-square for qualitative data and independent *t* test for continuous variables using non-parametric statistical tests, Mann-Whitney test. A value of $P < 0.05$ was considered statistically significant.

Results

Eleven patients with ischemic stroke showed MV in the ICA course at the extracranial part, proximal to the bifurcation of CCA on screening, and giving a relative frequency of MV in the ICA course 10.8%.

The mean age of these patients with MV in the ICA course was 68.91 ± 7.3 years old and ranged from 60 to 80 years old, suggesting that the observed MV were acquired in etiology. Six of them were females (54.5 %) and 5 were males (45.5%) (Table 1).

All patients with MV had medical risk factors for IS in addition to MV. Nine of them (81.8%) had combined DM and hypertension, and two cases (18.2%) had either DM or hypertension. Ten cases (90.9%) with ICA MV showed ICA stenosis $< 50\%$ and one of them showed ICA stenosis $< 50\%$ bilaterally, while no ICA stenosis was observed in one case (9.1%). ICA stenosis $\geq 50\%$ was not recorded in any case.

The pattern of ICA MV was tortuous in 7 cases (63.6%) and kinking in 4 cases (36.4%). These MV were recorded unilateral in majority (90.9%) of the cases and bilateral in one case only (9.1%). Our data revealed that the MV predominated in the left ICA (72.7%) than in the right (27.3%) (the clinical data of patients with MV in ICA are illustrated in Table 2).

The clinical rating scales of these patients for neurological deficit and functional state assessment showed that the mean NIHSS score was 15.2 ± 4.4 ranging from 2 to 22 and mRS was 4 ± 1.1 . We found no significant difference between the scores of NIHSS and mRS in both groups, $P > 0.05$ (see Table 3). The history of previous IS and TIA was recorded in 9.1% of patients with MV in ICA for each group, while the history of IS was recorded in 13.2% of patients without MV and TIA in 4.3% patients without MV in ICA. There were no statistically significant differences between both groups, $P > 0.05$.

Neuroimaging of patients with ICA MV showed multiple lacunar infarction in 54.5% ($n = 6$ cases), massive infarction in 27.3% ($n = 3$ cases), and White matter ischemia in 18.2% ($n = 2$ cases). Patients' individual data are illustrated in Table 2. A comparison between demographic data, clinical presentation, risk factors for CVS, and history of previous cerebrovascular insult as well as TIA preceding the current insult among patients with versus without MV in the ICA course shows no significant differences between groups in any of these items (Table 3).

Discussion

This study aimed to estimate the prevalence of MV in the ICA course among ischemic stroke patients and it was 10.8%. Tortuosity was the commonest MV observed in our patients (63.6%), followed by kinking (36.4%). There were no differences in the liability to IS or TIA among patients with MV and without, and the stroke severity among both groups was not affected by the presence of the MV.

Table 1 Demographic and clinical data of ischemic stroke patients with and without internal carotid artery morphological variations

	Patients with MV in the ICA course (n = 11)	Patients without MV in the ICA course (n = 91)	P value
< 60 years	0 (0%)	23 (25.3%)	0.075
≥ 60 years	11 (100%)	78 (85.7%)	
Sex			0.653
Male	5 (45.4%)	35 (38.5%)	
Female	6 (54.6%)	56 (61.5%)	
Clinical presentation			0.631
Right-sided hemiplegia or hemiparesis	7 (63.6%)	51 (56%)	
Left-sided hemiplegia or hemiparesis	4 (36.4%)	40 (44%)	
Risk factor			0.179
Negative risk factor	0 (0%)	13 (14.4%)	
Positive risk factors	100%	78 (85.7%)	
One risk factor (D.M. or HTN)	2 (18.2%)	19 (20.8%)	
Two risk factors	9 (81.8%)	59 (64.8%)	

D.M. diabetes mellitus, HTN hypertension, MV morphological variations, ICA internal carotid artery

Various studies [14–16] have found that ICA MV was associated with ischemic stroke. Cerebral ischemia from ICA MV occurs through two mechanisms: a thromboembolic mechanism from endothelial lesions due to changes in the local flow at the site of arterial bending, and/or a hemodynamic mechanism (hemodynamic stroke) that plays an important role under both neutral and dynamic conditions.

Sacco and colleagues [17] used carotid ultrasound to study ICA MV among 1217 patients, 12.7% only of them had IS or TIA. They found that the prevalence of MV among the whole population was 26.2% which is much higher than our prevalence. This could be attributed to the difference in the sample size, selection criteria of the study population, and ethnicity. They did not find any difference between sexes under the age of 60, while above the age of 60, the prevalence of MV was higher in

women than in men. Like our results, we found an insignificant higher prevalence rate among females. A more prominent change in vessel wall morphology among females could be linked to hormonal processes especially among postmenopausal women [7]. The tortuosity and kinking were the commonest ICA MV reported by them, and they were more frequently found on the left side which was in concordance to our results. Like our results, they did not show any relationship between ICA MV with IS or TIA.

Togay-Isikay et al. [13] studied 345 consecutive patients using carotid ultrasound, 102 patients out of them had stroke and TIA. They found that the prevalence of MV among all study population was 24.6%, and among patients with a history of IS or TIA, it was 15.7% which is slightly higher than ours. Kinking followed by tortuosity was the most common MV encountered by them

Table 2 Individual data for patients with internal carotid artery morphological variations

Clinical presentation	Age	Sex	Risk factor	NIHSS	Rt ICA	Lt ICA
Lt hemiplegia	75	Male	D.M., HTN	22	Occluded	Tortuous with stenosis < 50%
Rt hemiparesis	60	Female	D.M., HTN	10	Normal	Tortuous with stenosis < 50%
Improved RT hemiparesis and dysarthria	65	Male	HTN	4	Normal	Mod kink stenosis < 50%
Rt hemiplegia	65	Male	D.M.	14	Normal	Mild kink stenosis < 50%
Triple stroke recent Rt	80	Male	D.M., HTN	18	Normal	Tortuous with stenosis < 50%
Lt hemiplegia	60	Female	D.M., HTN	18	Tortuous with stenosis < 50%	Tortuous with stenosis < 50%
Rt hemiplegia	80	Female	D.M., HTN	20	Normal	Mild kink stenosis < 50%
Rt hemiplegia	66	Female	D.M., HTN	14	Mild kink with a normal lumen	Normal
Rt hemiparesis	75	Female	D.M., HTN	8	Tortuous with stenosis < 50%	Normal with stenosis < 50%
Rt hemiplegia	67	Male	D.M., HTN	16	Normal	Tortuous with stenosis < 50%
Lt hemiplegia	65	Female	D.M., HTN	12	Normal	Tortuous with stenosis < 50%

NIHSS, Barthel, is a clinical rating scale for stroke. Lt left side, Rt right side, D.M. diabetes mellitus, HTN hypertension, ICA internal carotid artery, DCL disturbed conscious level

Table 3 Demographic and clinical data of ischemic stroke patients with and without internal carotid artery morphological variations

	Patients with MV in the ICA course (n = 11)	Patients without MV in the ICA course (n = 91)	P value using the chi-square or T test
History of cerebrovascular insult			
• TIA	1 (9.1%)	4 (4.3%)	0.495
• CVS	1 (9.1%)	13 (14.3%)	0.739
Neuroimaging findings			
Normal CT brain	0 (0)	5 (5.2%)	0.065
Lacunar infarctions	7 (63.6%)	30 (33%)	
Massive infarction	3 (27.2%)	35 (48.4%)	
Multiple infarction	1 (9%)	16 (17.4%)	
Old infarctions	1 (9%)	1 (1%)	
White matter ischemia	2 (18.2%)	1 (1%)	
NIHSS	15.2 ± 4.7	15.2 ± 4.4	0.886

MV morphological variations, ICA internal carotid artery, TIA transient ischemic attack, CVS cerebrovascular stroke, NIHSS National Institute of Health Stroke Scale

which was different from our findings. Unlike our results, they observed statistically significant MV in females > 60 years, while there was no sex difference in patients < 60 years. Their patients' MV were bilateral in CA in 48%; in the remaining patients, the MV of the left side were common than those of the right like our results. They noticed that MV have no significance as a risk factor for stroke or any cerebrovascular disease.

Martins and colleagues [7] studied 19,804 patients with multiple risk factors not including IS (D.M., AF, hypertension, and hyperlipidemia). They used carotid ultrasound and detected MV of the ICA among 13.52% among their patient, which is slightly higher than our prevalence. Kinking followed by coiling was the most common MV detected by them which was not in concordance with our results. The prevalence of MV was higher among older age and female patients and was in the left ICA in most patients. Again, their results were in concordance with the results of our study. Contrary to our results, they observed that only kinking of ICA was significantly correlated with IS. Moreover, they found significant hemodynamic disorders in the ICA associated with kinking, which related to the occurrence of IS. The differences between their findings and ours could be attributed to their large sample size and the small number of patients with kinking examined by us.

Our results were higher than the rate recorded by Yi-Sin study [6] who used carotid ultrasound to study the prevalence of ICA MV among 615 patients with various risk factors (D.M., hypertension, IS, and hyperlipidemia). He found that the prevalence among the general population was 4.1% and the prevalence among IS patients was 4.7% only. The big differences between our MV prevalence and his prevalence could be attributed to the different ethnicity as the Asian population has intracranial

vascular changes common than extracranial vascular changes [18, 19]. He found also that ICA MV are not related to IS occurrence and stroke severity, which was like our findings. From previous results, we could conclude that the prevalence of MV among the Egyptian population lies midway between high prevalence among Caucasians and low prevalence among the Asian population.

Beigelman et al. [20] examined 60 consecutive stroke patients with carotid kinking using carotid ultrasonography and found no differences between flow velocity assessed at the level of kinking compared to the normal vessel. They concluded that carotid kinks are not a mechanism of acute cerebral ischemia which was similar to our results.

Sang Mi-Noh and Kang [21] examined 27 stroke patients using CTA to examine the relation between carotid artery morphology and the occurrence of IS, and they found that ICA MV has a significant impact on the IS occurrence. These positive results could be attributed to the use of CTA in their research which made them detect more number of MV in addition to their small sample size which made positive relation more likely.

Conclusion

Morphological variations in the course of the internal carotid artery are frequently observed during carotid ultrasound study. According to our study, their presence was associated with aging, female gender, and vascular risk factors as diabetes and hypertension. The results of this study also indicate that MV are not associated with an increased risk of ischemic stroke. Further large population-based studies are encouraged to estimate whether MV are associated with an increased risk of CVS or not.

Abbreviations

MV: Morphological variations; ICA: Internal carotid artery; TIA: Transient ischemic attack; CVS: Cerebrovascular stroke; NIHSS: National Institute of Health Stroke Scale; D.M.: Diabetes mellitus; HTN: Hypertension; IS: Ischemic stroke

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Authors' contributions

NA: supervisor and data analysis. HA: acquisition of data and study design. MN: acquisition of data and data analysis. AN: acquisition of data, study design, and editing of the manuscript. The authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study protocol was approved by the ethical committee at the Faculty of Medicine, Assuit University, in October 2016 with IBR no. 17101047. All participant patients or their 1st degree of relatives were giving informed consent for the participation in the study before assessment. All patients' data were confidentially kept.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests in this section.

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