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Relation between Carotid Artery Plaques Characteristics as a Predictor of Haemodynamics Changes after Carotid Artery Stenting

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Abstract

Objectives: To study relationship between carotid artery plaques characteristics and haemodynamic changes after carotid stenting. **Patients and Methods:** This observational prospective (pilot) study included 20 patients—who underwent CAS. The study was carried out in Ain shams university hospitals—Railway hospital (ERMED) and Suez insurance hospital from December 2018 to February 2020. Inclusion criteria, Symptomatic (defined as amaurosis fugax, TIA, Minor stroke or Major stroke) stenosis > 70%. Asymptomatic stenosis > 80% (accidentally discovered during pre-operative assessment for CABG and during full assessment for irrelevant stroke). **Results:** Regarding to plaque character for degree of stenosis, calcification and ulceration revealed significantly higher degree of stenosis in hemodynamic events group (P = 0.024). On the other hand, that there was no statistically significant difference between the two groups as regard calcification, ulceration and lesion location. **Conclusion:** The study revealed that HI is a common occurrence following CAS procedures and significantly higher degree of stenosis in hemodynamic events group. Plaque shape, ulcerations hardly affect haeodynamic instability after carotid stenting.

Keywords

Carotid Artery Plaques, Carotid Stenting , Haemodynamics, Carotid Stenosis

1. Introduction

Cerebrovascular disease is a leading cause of death and a major cause of permanent neurological and physical impairment in adults. In the United States, cerebrovascular disease is the second most common cause of death, with approximately 795,000 strokes occurring each year.

Carotid revascularization prevents recurrent ischemic stroke in patients with significant symptomatic carotid artery stenosis. Carotid endarterectomy has been the gold standard treatment for symptomatic significant carotid artery stenosis for more than 60 years [1]. Carotid artery stenting (CAS) (or carotid artery stent implantation) has developed rapidly over the last 30 years, and its frequency is increasing because it is less invasive than carotid endarterectomy with a low risk of cardinal injury and fewer surgical complications [2].

The revascularization of the carotid artery stenosis by CEA rapidly resolves chronic pressure differences in patients, so that a large blood flow and high blood pressure are delivered to the brain parenchyma without adaptation. Most patients show cerebral vasoconstriction from autoregulation of the brain, and elevated perfusion pressure is restored to a normal level within a few minutes due to this mechanism in CAS. However, in some patients, this auto-regulating ability is impaired due to long-term excessive lowering of cerebral blood flow, which can result in persistently elevated intracranial pressure (lasting from a few hours to days), thereby causing hyperperfusion syndrome [3].

Prediction of hypotension after CAS is important for preventing periprocedural ischemic complications. Diabetes mellitus, severely calcified plaque, balloon dilatation pressure, octogenarians, contralateral occlusion, female sex, distance from carotid bifurcation to maximum stenotic lesion, eccentric plaque formation, open-cell stent, and asymptomatic lesion are the reported risk factors that are independently associated with hemodynamic depression after CAS [2].

2. Aim of the Work

This study aims to assess relation between Carotid artery plaques characteristics as a predictor of Haemodynamics changes after carotid artery stenting.

3. Patients and Methods

This observational prospective (pilot) study included 20 patients—who underwent CAS.

Setting of the Study:

The study was carried out in Ain shams university hospitals—Railway hospital (ERMED) and Suez insurance hospital from December 2018 to February 2020.

Inclusion criteria:

1) Symptomatic (defined as amaurosis fugax, TIA, Minor stroke or Major stroke) stenosis> 70%.

2) Asymptomatic stenosis > 80% (accidentally discovered during pre-operative assessment for CABG and during full assessment for irrelevant stroke).

Exclusion criteria:

General exclusion criteria:

1) Major functional impairment (modified Rankin Scale ≥ 3).

2) Significant cognitive impairment (demented patients).

3) Major stroke within 4 weeks.

4) Contraindication to aspirin or clopidogrel (allergy, thrombocytopenia, GIT hemorrhage of <3 months).

5) Intracranial aneurysm > 2 mm or AVM requiring treatment.

Lesion-specific exclusion criteria:

1) Inability to achieve safe vascular access.

2) Visible fresh thrombus on the lesion.

3) Chronic total occlusion.

4) Long subtotal occlusion (string sign length 3 cm).

5) Heavily calcified lesion.

***Before procedure*:**

1) Consents were taken from all subject of the study.

2) Complete history taking from patient or relatives including past medical history of any of the following risk factors: arterial hypertension, diabetes mellitus, cigarette smoking, cardiac disease, dyslipidemia, peripheral vascular disease, previous stroke, transient ischemic attack, and/or reversible ischemic neurological deficit.

3) General examination including vital signs including HR and BP, heart and chest full examination.

4) Clinical and neurological examination with assessment by National Institutes of Health Stroke Scale (NIHSS) and patients were classified as one of the following:

* Minor stroke: new neurological deficit with NIHSS ≤ 8 [4].

* Moderate Stroke: new neurological deficit with NIHSS 9 - 15.

* Major Stroke: new neurological deficit with NIHSS ≥ 16.

5) Evaluation of patients with modified Rankin Scale (mRS).

6) Imaging:

* Carotid Artery Imaging, all carotid lesions were initially evaluated with Duplex ultrasonography (US) with high-frequency probes.

* Computed tomography angiography (CTA) or magnetic resonance angiography (MRA) were performed. Preprocedural CT imaging or MRI of the brain with diffusion was done in all cases.

* Angiographical measurement of the stenosis was determined by the North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria as follows:

- The view showing the greatest degree of ICA narrowing was chosen for analysis.

- The site of greatest ICA stenosis and the diameter of the distal cervical ICA were measured.

- The percent angiographic ICA stenosis was then calculated based on the distal cervical ICA.

7) Investigations were done including:

* Laboratory investigations (complete blood picture, PT, PTT, liver and renal

function tests, random blood sugar, lipid profile)

* Electrocardiogram and echocardiogram.

8) Patients were premedicated with aspirin (81 to 325 mg/day) and clopidegrel (75 mg/day) > 5 days pre-intervention. Routine antihypertensive medications on the morning of the procedure were held.

9) Prophylactic Atropine: Significant bradycardia is very common with carotid balloon dilatation (0.6 - 1 mg) prior to carotid bulb dilatation.

During the procedure:

* 100 U/kg of heparin was given for anticoagulation and before balloon inflation 1 mg atropine was administered to all patients.

Description of the procedure:

* With patients under local anesthesia, all cases were performed via the femoral approach. An 8 F guiding catheter or long sheath was advanced to the common carotid artery (CCA) under systemic heparinization (ACT between 250 and 300 seconds).

* All catheters were suctioned and flushed to remove any air bubbles prior to diagnostic imaging. The contrast syringe was kept relatively free of blood in order to minimize the risk of thrombus formation in the syringe and catheter. In addition, the contrast syringe is orientated at an angle (>30˚) during injections to prevent the introduction of air into the system.

* Aortic Arch Angiography: To obtain the images, a 5 Fr catheter was advanced to the ascending aorta just proximal to the innominate artery. The image intensifier was positioned in the LAO 45˚ - 60˚ projection which opens out the arch and separates the origins of the great vessels.

* Selective Carotid Angiography: The origin of the vessel of interest was then selectively engaged (usually by counterclockwise rotation). A roadmap image was constructed usually in an ipsilateral 20˚ - 30˚ view, although angles could vary according to individual anatomy. A standard imaging sequence was an ipsilateral 30˚ view of the carotid bifurcation (RAO for the right carotid and LAO for the left) followed by a left lateral view (LAO 90˚ for both vessels) (**Figure 1**).

Figure 1. Anteropsterior and lateral views for DAS carotid system

* Other views that were used are PA (posteroanterior), contralateral 30˚ and ipsilateral 60˚ views with caudal or cranial angulations.

* The culprit lesion was visualized in at least two different projections pre and post procedure and the intracranial circulation was visualized in all patients before and after the procedure.

* As with all imaging using DSA, the patient must not move. Therefore, the patients were instructed to hold still, hold their breath, and not swallow.

Carotid stenting:

* Twenty patients were treated with WallStent® stent except one patient with RoadSaver® Stent. In tight, sub-occlusive carotid stenosis pre-dilation was done using low profile (2 - 3 in diameter) 0.014-inch wire compatible balloons. After stent placement post-dilatation (if needed) was done using (3.5 - 6 mm in diameter) balloons and a plain film of the neck was obtained in different oblique projections to document the expansion of the stent.

* At the end of the procedure, the arterial introducer was removed, and homeostasis was accomplished by manual compression.

Embolic protection devices (EPD):

In protected patient group, a distal EPD was used We used SpiderFx embolic protection system, and Filter Wire EZ.

Technical success:

Defined as successful treatment of the stenosis with residual stenosis of ≤ 30% in at least two matched views on angiography.

End point:

Was defined as ipsilateral transient ischemic attack (TIA), ipsilateral ischemic stroke and vascular death.

Neurological complications:

Complications were classified as one of the following:

* Minor stroke: new neurological deficit with NIHSS ≤ 8.

* Moderate Stroke: new neurological deficit with NIHSS 9 - 15.

* Major Stroke: new neurological deficit with NIHSS ≥ 16.

* Transient ischemic attack (TIA): new neurological new neurological deficit with deficit that resolves completely within 1 hr.

Postprocedural management:

* Aspirin 150-mg PO QD indefinitely.

Clopidogrel 75-mg PO QD for three months after the procedure and ± Enoxaparin 40 units SC/12 hours for 7 days.

* Oral vasopressor (Pseudoephedrine): Patients with sustained hypotension can usually be treated with regular oral pseudoephedrine 30 - 60 mg q4 hourly prn or low-dose peripheral vasoconstrictor infusions. The aim should be to keep the systolic blood pressure between 90 and 140 mmHg, depending on the patient's pre-procedural blood pressure, to ensure adequate cerebral perfusion pressure and minimize the risk of stent thrombosis.

* Diffusion-weighted magnetic resonance imaging was done within 24 hours

after the procedure.

* Hospital stay: Patients unless complicated were discharged the next day of the procedure.

* Blood pressure and heart rate assessment was done immediately after and 2 weeks after procedure

Data management and Analysis:

The collected data was revised, coded, tabulated and introduced to a PC using Statistical package for Social Science (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Data was presented and suitable analysis was done according to the type of data obtained for each parameter.

I. Descriptive statistics:

1) Mean, Standard deviation (± SD), median and range for parametric numerical data.

2) Frequency and percentage of non-numerical data.

II. Analytical statistics:

1) Independent T Test: was used to assess the statistical significance of the difference between two study group means.

2) Correlation analysis (using Spearman's method): To assess the strength of association between two quantitative variables. The correlation coefficient denoted symbolically "r" defines the strength and direction of the linear relationship between two variables.

3) Chi-Square test was used to examine the relationship between two qualitative variables.

4) Mann-Whitney U Test: a non-parametric test used for assessment of the statistical significance of differences between two independent sample groups that did not fulfill the assumption of normal distributions.

5) Kruskal-Wallis test: a non-parametric method for testing whether samples originate from the same distribution. It is used for comparing two or more independent samples of equal or different sample sizes.

III. P- value: level of significance:

$P > 0.05$: Non-significant.

$P \leq 0.05$: Significant.

$P \leq 0.01$: Highly significant.

4. Results

Hemodynamic events which including; significant hypotension, and bradycardia, occurred among 8 cases immediately after stenting and the other 12 cases had no hemodynamic events.

I-Concerning age and sex:

- Among cases without hemodynamic events, there were 5 females (42%) and 7 males (58%). Their age ranged from 50 to 76 years (mean ± SD 65.42 ± 7.89).

- While among cases with hemodynamic events, there were 3 females (38%) and 5 males (62%). Their age ranged from 50 to 84 years (mean ± SD 64.63 ± 11.61).

This table shows that there was no statistically significant difference between cases with and without hemodynamic events as regard Age and sex (Table 1).

II-Plaque Characteristics:

Comparison between groups regarding to degree of stenosis, calcification and ulceration as shown in (Table 2, Figure 2, Figure 3) revealed significantly higher degree of stenosis in hemodynamic events group (P = 0.024). On the other hand, that there was no statistically significant difference between the two groups as regard calcification, ulceration and lesion location. In the case of no Hemodynamic events group (75.0%) has calcification and (83.3%) has ulceration.

Table 1. Comparison between Hemodynamic events regarding to Demographic data.

		Hemodynamic events		Test value	p-value	Sig.
		No	Yes			
		No. = 12	No. = 8			
Age	Mean ± SD	65.42 ± 7.89	64.63 ± 11.61	0.182•	0.857	NS
	Range	50 - 76	50 - 84			
Sex	Female	5 (42%)	3 (38%)	0.035*	0.852	NS
	Male	7 (58%)	5 (62%)			

Table 2. Comparison between Hemodynamic events regarding to plaque characteristics.

		Hemodynamic events				Test value	p-value	Sig.
		No		Yes				
		No.	%	No.	%			
Degree of stenosis	(70 - 79)	9	75.0%	3	37.5%	7.500	0.024	S
	(80 - 89)	3	25.0%	1	12.5%			
	>90	0	0.0%	4	50.0%			
Calcifications	No	3	25.0%	2	25.0%	0.000	1.000	NS
	Yes	9	75.0%	6	75.0%			
Ulceration	No	10	83.3%	4	50.0%	2.540	0.111	NS
	Yes	2	16.7%	4	50.0%			
Lesion location	Right ICA	2 (16.7%)		1 (12.5%)		4.722*	0.451	NS
	Right CCA/ICA	1 (8.3%)		1 (12.5%)				
	Left ICA	2 (16.7%)		0 (0.0%)				
	Left CCA/ICA	1 (8.3%)		1 (12.5%)				
	Both ICA	6 (50.0%)		3 (37.5%)				
	Both CCA	0 (0.0%)		2 (25.0%)				

P-value > 0.05 Non-significant (NS); P-value < 0.05: Significant (S); Chi-square test; •: Independent t-test.

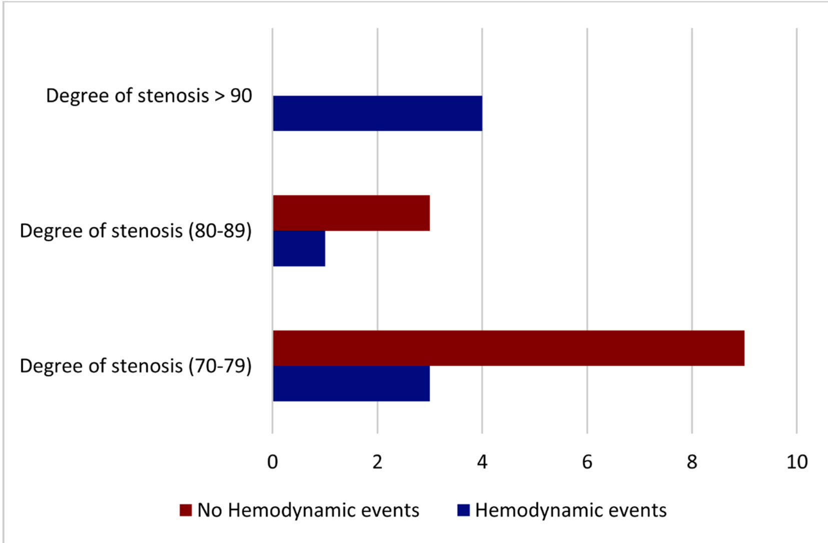

Figure 2. Comparison between the Hemodynamic changes regarding to degree of stenosis.

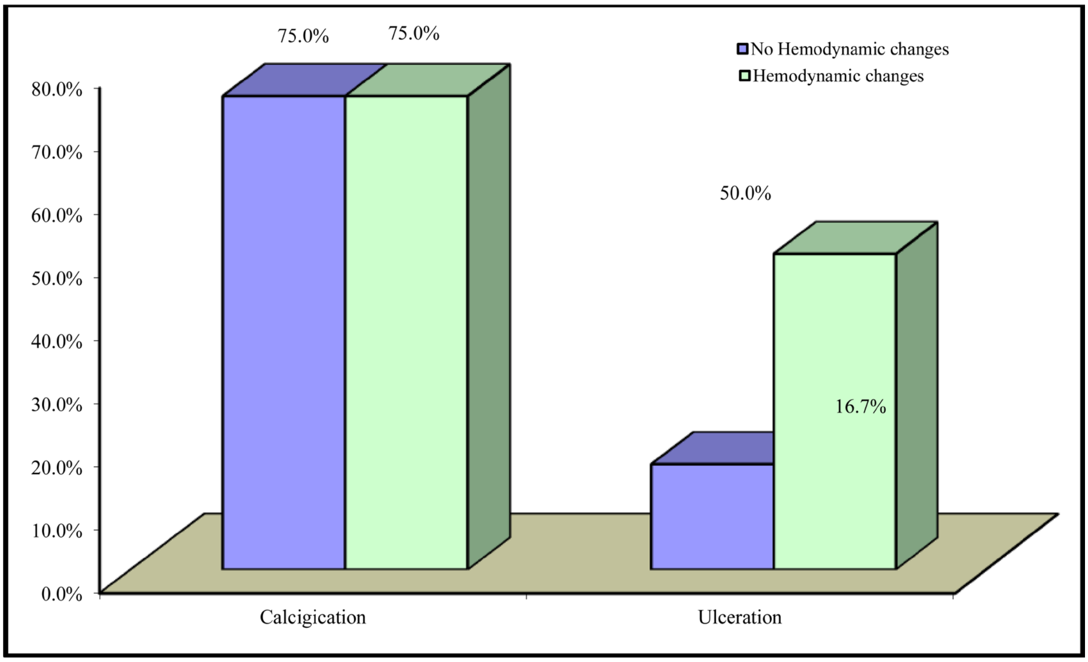

Figure 3. Comparison between the Hemodynamic events regarding to Calcification and Ulceration.

In the case of Hemodynamic events group (75.0%) has calcification and (50.0%) has ulceration.

5. Discussion

Carotid stenting (CAS) represents an alternative to conventional carotid endarterectomy (CEA) in certain patient populations. Hemodynamic instability (HI) has long been associated with CEA and has been linked to adverse clinical events [5].

Similarly, catheter-related instrumentation of adventitial baroreceptors at the level of the carotid sinus, along with balloon angioplasty and stent deployment, may trigger a baroreceptor reflex and result in a variety of hemodynamic derangements following CAS procedures [6].

There are conflicting reports in the literature regarding the true incidence and relative clinical impact of periprocedural hemodynamic instability (HI) in patients undergoing CAS procedures. Hemodynamic depression, including the presence of bradycardia or hypotension, has been cited to occur in 5% to 76% of CAS procedures. Extreme or prolonged (>1 hour) episodes of periprocedural HI after CAS have been shown in some studies to be associated with worse clinical outcomes [7].

Carotid artery stenting (CAS) (or carotid artery stent implantation) is a method of carotid revascularization, which has developed rapidly over the last 30 years. To date, the frequency of use of CAS is increasing, and clinical outcomes are improving with technical advancements. Complications associated with CAS include cerebral infarction, cerebral hemorrhage or hyperperfusion syndrome, complications associated with the site of stent insertion, protective device-related complications, systemic complications, and local complications at the puncture site [8].

Although baroreceptors have a short-lasting effect, prolonged HI can occur due to prolonged sinus activation and predominant sympathetic activity after the procedures. Prolonged HI can result in serious complications including acute cerebral infarction, intracranial hemorrhage (ICH), myocardial infarctions, and renal failure. Accordingly, hemodynamic stabilization is important during and after interventional procedures, especially for patients at a high risk for HI [7].

The main purpose of the study was to assess the predictors of hemodynamic events peri-carotid artery stenting. This is a prospective observational study that was conducted at Ain shams university hospitals—Railway hospital (ERMED) and Suez insurance hospital, the study was conducted on 20 patients who have significant carotid artery stenosis.

The current study included 8 patients with hemodynamic events (40%) and 12 patients without hemodynamic events (60%).

Nonaka *et al.*, (2005) [9] determined that distance between carotid bifurcation and maximum stenotic lesion, type of stenosis on angiogram, fibrous plaque morphological features and calcifications at carotid bifurcation on ultrasonograms were independent risk factors of postprocedural hypotension. Gupta *et al.*, (2006) mentioned that carotid pulp and calcified plaque were significantly predictive of development of postprocedural HI. Moreover, Taha *et al.,* (2008) [10] mentioned that laterality, carotid bulb lesions, eccentric posterior carotid plaque and general anesthesia were associated significantly with postprocedural HI. Larger number of included patients in all three mentioned articles could be the explanation to different results compared to our study.

The present study revealed that there was statistically significant difference between the two groups as regard degree of stenosis (p = 0.024).

6. Conclusion

The study revealed that HI is a common occurrence following CAS procedures and significantly higher degree of stenosis in hemodynamic events group. Plaque shape, ulcerations hardly affect haemodynamicsinstability after carotid stenting.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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