Ref: Ro J Neurol. 2023;22(3)
DOI: 10.37897/RJN.2023.3.7

Association of carotid artery stenosis and ischemic stroke in patients undergoing coronary artery bypass grafting

Arifa Rahman[1], Swarna Deepak Kuragayala[2], Sandeep Nayani[3]

[1]Department of Neurology, KIMS Secunderabad, Telangana, India
[2]Department of General Medicine, Apollo Institute of Medical Sciences and Research, Hyderabad, Telangana, India
[3]Apollo Health City, Hyderabad, Telangana, India

ABSTRACT

Background. The incidence of stroke after Coronary artery bypass grafting (CABG) and the effect of carotid artery stenosis for risk assessment of stroke was strongly needed. This study compared the relation of ischemic stroke in the patients posted for CABG with varying degree of carotid artery stenosis (CAS) as measured by carotid artery Doppler.

Patients and methods. This prospective cross-sectional study enrolled 422 patients with coronary artery disease (CAD) who underwent CABG. Out of them 170 patient with concomitant CAD were selected and divided into three groups such as mild, moderate and severe CAS. The occurrence of stroke was measured.

Results. Unilateral CAS was common than bilateral CAS (71.2% vs 28.8%). Mild CAS was more than moderate and severe CAS (72.4% vs 21.2% vs 6.5%). Stroke observed in 1.2%, in which one patient had moderate CAS and other had severe CAS on the side of clinical stroke post CABG. Right carotid disease was frequent among 3 groups (51.8% vs 47.6%; 11.8% vs 10.6%; 4.1% vs 3.5%). Patient with old stroke showed significant correlation with the severity of CAD (p=0.02). Post-surgery stroke had significant correlation with previous history of stroke (p=0.001), severity of CAD (p=0.01) and bilateral CAS (p=0.02). Post-operative low volume state requiring prolonged ionotropic support showed significant correlation to stroke (p=0.02).

Conclusion. Screening of patients for CAS in patients age >65 years with previous stroke, and comorbidities aids the surgeon to take required measures to prevent stroke as a complication intraoperative or postoperative and decrease morbidity to the patient.

Keywords: stroke, carotid artery stenosis, coronary artery disease, coronary artery bypass grafting

INTRODUCTION

Carotid artery stenosis (CAS) is a complication of systemic atherosclerotic disease. Classical types of lesion are fatty streaks, fibrous cap, and complicated lesion, based on the progression of atherosclerosis. Carotid plaques are made up of a lipid core with inflammatory cell infiltration and a fibrous cap. Vulnerable or unstable carotid plaques are characterized by active inflammation, substantial macrophage buildup, a thin cap with a big lipid core, endothelial denudation with superficial platelet aggregation, fissures, and severe stenosis [1]. The vulnerable plaques are more prone to rupture, resulting in thromboembolic events [2]. Inflammation of the fibrous cap occurs more frequently in non-calcified plaque than in calcified plaque, implying that plaque calcification is a measure of plaque stability [3-5].

CAS is observed in 2.4 to 14% of patients with CAD those undergoing CABG [6-8]. The stroke incidence in stenosis <80% is 1% while it increases to 4.8% in stenosis greater than 90% [9]. Globally the occurrence of perioperative stroke after cardiac surgery ranges from 0.8% to 5.2 % [10].

Perioperative stroke, defined as a new onset neurologic deficit within 30 days of surgery, is one of the most featured consequence of CABG [11]. The report-

Corresponding author:
Dr. Swarna Deepak Kuragayala
E-mail: drksdeepak@gmail.com

Article History:
Received: 19 August 2023
Accepted: 1 September 2023

ed incidence of perioperative stroke is 1.6% [12]. Approximately 40% of strokes occur intraoperatively, and the majority of the remaining strokes occur within the first 48 hours after surgery [13].

The most common mechanism for perioperative stroke described was embolism [14,15].

Carotid artery stenosis is usually assessed by Carotid artery duplex ultrasound, to visualize the plaques and their quantification of the stenosis [16].

We conducted this by including the consecutive patients undergoing CABG and subjected them for carotid Doppler study by an experienced Radiologist.

Currently there are limited studies on this important subject including our patient population from India.

AIM OF THE WORK

We undertake this study to identify the prevalence of CAS among patients undergoing CABG and to study its association with risk of Stroke among our patient population.

PATIENTS AND METHODS

Study setting: Department of Neurology, and Department of Cardiothoracic surgery, Apollo Hospitals, Hyderabad

Study population: All adult CAD patients with New York Heart Association classification I–III those were elective CABG.

Study duration: 11 months, January 2021 to November 2021.

Study design: Retrospective and Prospective observational study.

Selection of patients: Simple random.

Inclusion criteria

- Adult patients of both genders with CAS scheduled for CABG who have Carotid Doppler performed preoperatively.

Exclusion criteria

- Patients of clinical history of carotid artery interventions.
- Patients undergoing emergency CABG.
- Patients of previous ischemic stroke history.
- Patients with no focal results from neurological examination like encephalopathy.

Calculation of Sample size was done based on previous study [17].

Incidence of strokes after cardiac surgery in carotid stenosis was 1.8% [17]. Considering the 95% level of confidence interval (Z=1.96) with 2% precision (d=0.02) the minimum required sample size is

$$n= (Z\alpha/2)^2 \times p \times (1 - p)/(d)^2$$

$$(1.96)^2 \times (0.018) \times (1 - 0.018)/(0.02)^2$$

$$= 169.76 \sim 170$$

The minimum required sample for the study is 170.

Study method:

1. Retrospective study data: patients that fulfilled the inclusion criteria and admitted to the hospital between January 2021 to August 2021 were selected from the cardiothoracic operation theatre-CABG register. Informed consent was not taken from patients selected in the retrospective data as a waiver applies.

2. Prospective study data: Patients fulfilling the inclusion criteria and exclusion criteria that were admitted for elective CABG were for prospective data collection from August to November 2021. For each patient, a study proforma containing detailed history of demographics, risk factors and complete neurological examination carried out.

Study procedure:

Carotid duplex ultrasound

Bilateral Carotid arteries initially assessed with high-resolution carotid duplex sonography, which was generally performed within a month before surgical date. The blood flow velocities in the common carotid, external, and internal carotid arteries (ICAs) were measured using color Doppler. ICA peak systolic velocity, ICA - common carotid artery ratio (ICA), and ICA end diastolic velocity (ICA) were quantified. The presence of plaque, calcification, and intimal thickening which affect the carotid vessels were noted.

Definitions:

Post-surgery assessment for stroke: Post-surgery patients monitored for new onset neurological deficit up to 7th day. CT and MRI scans were done if focal neurological deficit is present on physical neurological examination to confirm or rule out ischemic stroke.

Postoperative stroke is characterized as prolonged (>24 hours) localized or multifocal neurological impairments (clinical stroke) that are best explained by brain ischemia.

Stroke: cortical/cerebellar lesions/subcortical/brain-stem lesions/lacunar stroke.

Dyslipidemia is such as fasting total cholesterol levels > 250 mg/dL.

The degree of carotid artery stenosis categorized as:

- Group 1 - Mild stenosis i.e carotid artery stenosis <50%
- Group 2 - Moderate stenosis i.e carotid artery stenosis between 51-69%

- Group 3 - Severe stenosis i.e carotid artery stenosis >70%.

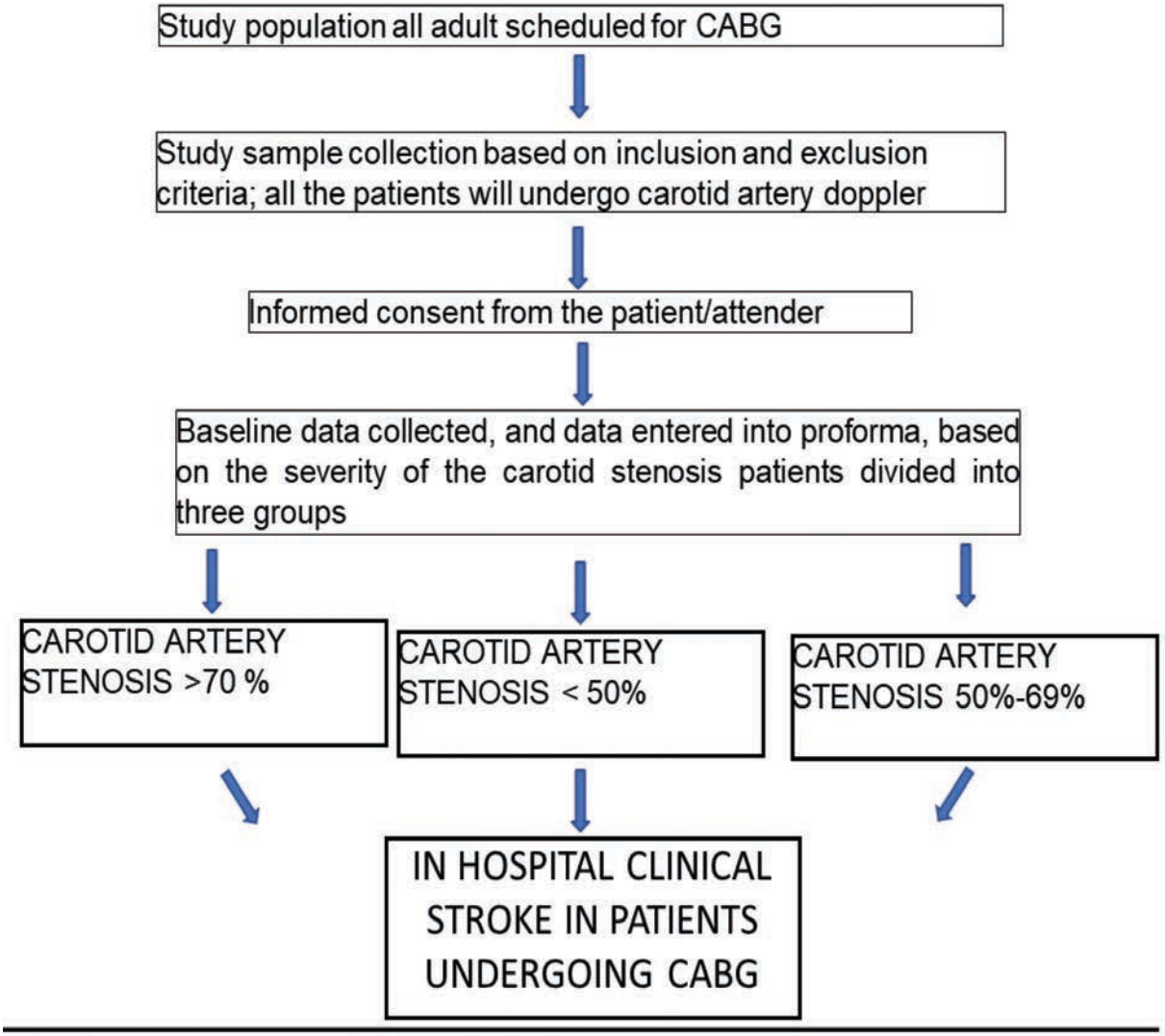
Statistical Analysis: statistical analysis was done by SPSS software Version 26 (IBM Inc, United States).

Variables of interest:

- Carotid Artery Stenosis (categorical variable): Measured before CABG
- Severity of Carotid Artery Stenosis categorized as Mild, Moderate, Severe (categorical variable).
- Stroke incidence after CABG (categorical variable).

Descriptive statistical analysis carried out for demographic and baseline characteristics.

STUDY FLOW CHART:



Quantitative analysis for continuous variables was expressed in means and standard deviation. Qualitative analysis for Categorical variables was expressed in frequency/percentages.

Chi-square test was used for qualitative data to test the association between Carotid Artery Stenosis, (Yes/No), Severity of Carotid Artery Stenosis (Mild, Moderate, Severe) and Incidence of Stroke (Yes/No). Independent t-test analysis has been performed to examine relationships between Age (continuous variable) and Incidence of Stroke. Chi-square test also have been used to test the association between Diabetes (Yes/No), Hypertension (Yes/No), Previous history of Stroke (Yes/No) and Incidence of Stroke after CABG (Yes/No). P value of <0.05 was referred as statistically significant.

RESULTS

A total of 422 patients with CAD underwent CABG in Apollo hospitals, Jubilee hills Hyderabad during the period of January 2021 to October 2021 and out of them patient with concomitant carotid artery disease were selected for the present study. Total Sample size of 170 patients and their data was obtained from the medical records and also few were obtained after taking informed consent. 170 patients with coronary artery disease as well

as carotid artery disease who underwent CABG were studied.

Majority of the patient who underwent CABG were under the age of 65 years (n=107, 62.9%) with carotid artery stenosis.

Out of 170 patients only 15.9 % were female and 84.1% were males, male to female ratio was 5.6:1.

Among study population who underwent CABG significantly higher number 94.7% (n=161) were diabetic, compared to 75% (n=128) were hypertensive and 52% (n=89) were dyslipidemia. Hypothyroidism in 4.7%, and CKD in 10.6% population (Table 1).

Among study population right carotid artery 51.8% had mild carotid disease (<50%) on right, moderate (51-69%) carotid disease was seen in 11.8% severe (>70) carotid disease were seen only in 4.1% (Table 2).

Among population who underwent CABG on 10 % (n=17) had previous history of stroke.

There was no statistically significant difference in distribution of patients among the groups based on gender. Severe carotid artery patients were seen in 100% males (Table 1).

Among study population left carotid artery 47.6 % had mild carotid disease (<50%) on right, moderate (51-69%) carotid disease was seen in 10.6% severe (>70) carotid disease were seen only in 3.5% (Table 4).

There were 2 patient had stroke during the study period and both were males. The male to female ratio in patients undergoing CABG is 5.6:1. In the study population among hypertensive patients 71% (n=91) had unilateral carotid artery disease and 28.9% (n=37) had bilateral carotid artery disease (Table 1).

In the study population among hypertensive patients 71% (n=92) had mild (<50) carotid artery stenosis 20.3% (n=26) had moderate (50-69) carotid artery stenosis and 7.8% (n=10) had severe (>70) carotid artery stenosis (Table 1).

TABLE 1. Distribution of unilateral and bilateral carotid stenosis and severity based on gender

Gender	Laterality		p-value*
	Unilateral N (%)	Bilateral N (%)	
Female	21(17.5%)	6(13.9%)	0.42
Male	100(82.6%)	43(87.7%)	
Total	121	49	
Hypertension			
No	30(24.7%)	12(24.4%)	0.96
Yes	91(75.2%)	37(75.5%)	
Diabetes			
No	4(44.4%)	5(55.5%)	0.069
Yes	117(72.7%)	44(27.3%)	
Dyslipidemia			
No	57(47.1%)	24(48.9%)	0.82
Yes	64(52.8%)	25(51.1%)	

**chi square test*

TABLE 2. Association between severity of carotid stenosis and gender, hypertension, dyslipidemia, diabetes, old stroke, and post CABG stroke distribution

Gender	Carotid artery stenosis severity			p-value*
	Mild (<50)	Moderate (50-69)	Severe ≥70	
Female	19(15.4%)	8(22.2%)	0	0.2
Male	104(84.5%)	28(77.7%)	11(100%)	
Hypertension				
No	31(25.2%)	10(27.7%)	1(9%)	0.44
Yes	92(74.8%)	26(72.2%)	10(90.9%)	
Diabetes				
No	6(48.7%)	3(8.3%)	0	0.44
Yes	117(95.1%)	33(91.6%)	11(100%)	
Dyslipidemia				
No	54(43.9%)	22(39.2%)	5(45.4%)	0.82
Yes	69(56%)	14(25%)	6(54.5%)	
Old Stroke				
No	112(73.2%)	32(20.9%)	9(5.8%)	0.021
Yes	11(64.7%)	4(23.5%)	2(11.7%)	
Post CABG Stroke				
No	123(100%)	35(97.2%)	10(90.9%)	<0.05
Yes	0	1(2.7%)	1(9%)	

**chi square test*

TABLE 3. Distribution of stroke based on gender, hypertension, diabetes, old stroke, inotropes, laterality and their association with unilateral vs bilateral carotid

Gender	No Stoke	Clinical Stroke	p-value*
Female	27(100%)	0	0.96
Male	141(98.6%)	2(1.3%)	
Hypertension			
No	42(100%)	0	**0.41**
Yes	126(98.4%)	2(1.5%)	
Diabetes			
No	9(100%)	0	**0.73**
Yes	159(98.7%)	2(1.3%)	
Old Stroke			
No	153(100%)	0	**< 0.001**
Yes	15(88.2%)	2(1.1%)	
Inotropes			
No	97(80.1%)	47(95.9%)	0.01
Yes	24(19.8%)	2((4.1%)	
Laterality			
Unilateral	121(72%)	0	0.02
Bilateral	47(27.9%)	2(100%)	
Total	121	49	

**chi square test*

Significant correlation noted between prolonged use of inotropes and perioperative stroke in post CABG subjects (Table 1).

In our study population, among the hypertensive patients, 72.7% (n=117) had mild (<50) carotid artery stenosis 20.4% (n=33) had moderate (50-69) carotid artery stenosis and 6.8% (n=11) had severe (>70) CAS (Table 2).

In our present study both two stroke cases occurred in the hypertensive subjects. In our study population among diabetic patients 72.7% (n=117) had unilateral carotid artery disease and 27.3% (n=44) had bilateral carotid artery disease. Both strokes occurred in the diabetic patients.

In the study population, 10% (n=17) had previous history of stroke in them 53% (n=9) had bilateral stenosis and 47% (n=8) had unilateral carotid artery disease. This was statistically significant association. In the study population 10% (n=17) had previous history of stroke in them 64.7% (n=11) had mild(<50) carotid artery stenosis, 23.5% (n=4) had moderate(50-69) carotid artery disease and 11.7% (n=2) had severe (>70) carotid artery disease. This was statistically significant association (Table 2).

No statistically significant difference noted between the comorbidities like hypertension and diabetes with in the three groups of carotid stenosis in between groups. Hypertension was mostly associated with mild stenosis n=67 out the 90 patient with right carotid artery stenosis, Diabetes mellitus was also associated with mild stenosis 82 out of 107 patients with right CAS.

No statistically significant difference observed between the comorbidities like hypertension and diabetes with in the three groups of carotid stenosis in between groups. Hypertension was mostly associated with mild stenosis 58 out the 75 patient with right carotid artery stenosis. Diabetes mellitus was also associated with mild stenosis, 77 out of 100 patients with right carotid artery stenosis.

Among study population who underwent CABG patient were almost equal in on pump (n=83) and off pump (n=87) groups. During the study period only two patients had stroke in the hospital post CABG who underwent both on and off pump CABG.

INTRA OPERATIVE FACTORS: Among total patients, two patients developed stroke with moderate carotid stenosis 52% in the right carotid and 65% in the left carotid artery, and stroke in left hemisphere of the brain as it was seen in the CT brain and by clinical right hemiparesis. The other patient who developed stroke underwent off pump CABG. Totally intra-aortic balloon pump (IABP) requirement for LV dysfunction were seen only in 11 % (n=19) of the total patients. In the study population IABP was used in study subjects with severe LV dysfunction it did not show statistical significance with the severity of carotid stenosis, no patient who had post- operative stroke was on IABP (p=0.97).

TABLE 4. Correlation of right carotid stenosis with comorbidities and correlation of left carotid stenosis with comorbidities

Comorbidities	Right carotid stenosis				p-value*
	None	<50	51-69	≥ 70	
Hypertension	38	67	16	7	**0.295**
Diabetes	54	82	18	7	**0.39**
Hypothyroid	**2**	**4**	**1**	**1**	**0.664**
Dyslipidemia	24	54	7	4	**0.071**
CKD	4	13	0	1	**0.192**
Comorbidities	**Left carotid stenosis**				**p-value***
Hypertension	53	58	13	4	**0.515**
Diabetes	61	77	17	6	**0.929**
Hypothyroid	**3**	**4**	**1**	**0**	**0.953**
Dyslipidemia	37	43	7	2	**0.433**
CKD	**7**	**9**	**2**	**0**	**0.863**

**chi square test*

POST OPEARTIVE FACTORS: In our study population, 16.5% (n=28) developed atrial fibrillation requiring prolonged antiarrhythmic management post-surgery. Totally 15.3% (n=26) subjects required prolonged ionotropic support post-surgery but the stroke which occurred in two patient did not require prolonged ionotropic support with moderate carotid stenosis.

Study outcome: In our study population of post CABG subjects with CAS the occurrence of stroke was present only in 1.2% (n=2) which had significant correlation with severity of carotid disease. Both strokes were on the left MCA territory (Table 5).

TABLE 5. Association old stroke with post CABG stroke

Old Stroke	No Stroke	Clinical Stroke	p-value
No	153(100%)	0	**< 0.001**
Yes	15(88.2%)	2(1.2%)	
Total	**168**	**2**	

In our study, both patients with bilateral carotid artery disease had stroke. There was statistical significance observed with bilateral disease and stroke (Table 1).

Statistical significance difference observed between the severity of carotid stenosis and clinical stroke post CABG.

In our study population, the incidence of stroke was 1.2% (n=2) out the 170 patient who underwent CABG and both of them had previous history of stroke this was statistically significant association (Table 5).

TABLE 6. Comparison of patient characteristics with severity of carotid artery disease

Parameter	Mild stenosis <50	Moderate Stenosis, 51-69	Severe stenosis, >70	P-value
Age (in years)	62.56±6.2	61.97±7.05	64.36±6.45	**0.54**
Sex ratio (M: F)	3.8:1	3.5:1	1:0	**0.21**
Hypertension	71.8%	20.3%	0.08%	**0.44**
Diabetes	72.6%	20.4%	0.06%	**0.51**
Dyslipidemia	77.5%	15.7%	0.06%	**0.18**
Old stroke	64.7% (n=11)	23.5(n=4)	11.7(n=2)	**0.02**
Post CABG stroke	**0**	**1(50%)**	**1(50%)**	**0.01**

TABLE 7. Comparison of patient characteristics of unilateral vs bilateral carotid disease

Parameter	Unilateral	Bilateral	P-value
Sex ratio (M: F)	9:1	8:1	0.42
Hypertension	71.1%	28.9%	0.96
Diabetes	72.7%	27.3%	0.69
Dyslipidemia	71.9%	28%	0.82
Old stroke	47% (n=8)	53% (n=9)	0.02
Post CABG stroke	0	100%	0.02

TABLE 8. Comparison of patient characteristics of post CABG stroke

Parameter	No Stroke	Clinical Stroke	P-value
Sex ratio (M: F)	5.2:1	1:0	0.42
Hypertension	98.4% (n=126)	1.5% (n=2)	0.41
Diabetes	98.7% (n=159)	1.3(n=2)	0.69
Bilateral CAS	95.9% (n=47)	4% (n=2)	0.02
Old stroke	88.2% (n=13)	1.1% (n=2)	0.001
Ionotropic support	92.3% (n=24)	17.6% (n=2)	0.02

DISCUSSION

Our study "Association of carotid artery stenosis and ischemic stroke in patients undergoing CABG" was carried in Department of neurology, Apollo Health City, Jubilee Hills, Hyderabad from January 2021 to November 2021. Totally 170 consecutive patients with CAS who underwent CABG were included and analyzed. The study demonstrated that Unilateral CAS was more common than Bilateral CAS. Mild CAS was more often found than moderate and severe CAS. Overall stroke has occurred in 2 patients of them; one had moderate CAS and the other patient with severe CAS.

Demographics

The mean age of our study subjects was 62.5 years. Raffa et al. [18] had the mean age of 65.4 years and in another study by Ruka E et al [19], also shows similar mean age. The mean age of the study subjects with stroke was higher, 66 years, when compared to those without stroke, 62.5 years. In accordance to our results, Tarakji et al. also observed that the mean of patients with stroke was significantly higher when compared to those without stroke (67 vs. 63 years). We also observed that the mean age among patients with severe CAS was higher 64.3 years when compared to mild and moderate degrees of CAS, which were 62.5 and 62 years respectively, though the difference was statistically significant. Similar to our results in a study be Taneja S et al. [20], the prevalence of moderate/severs CAS was 20% among patients more than 65 years of age whereas the prevalence was 11% among study subjects < 65 years of age.

In our study, advancing age did not show statistical significance with the severity of carotid stenosis (p=0.54), however >70 % stenosis was noted in study subjects in the age group of >65 years (64.36±6.45 yr).

The majority patients in the study were males, 84%, with male to female ratio 5.6:1. Also, among all 3 severity groups of CAS, majority were males. Mild CAS had 84.5%, moderate CAS had 77.7% males. Most of the studies also show that majority were males [21,22]. In our study, both the patients who had stroke were males. The difference that we observed with the mentioned studies could be because of relatively large sample size in those studies.

In our study, male preponderance was seen in the study but did not show any statistical significance in the severity of carotid artery disease (p=0.21) or post CABG stroke (p=0.91).

Comorbidities

In our study, diabetes (p= 0.51 and p= 0.69), hypertension (p= 0.44 and p= 0.96), dyslipidemia (p=0.18) did not show any significant correlation with severity of CAS and post-surgery stroke diabetes was noted in 94.7% of study population.

Diabetes was present in almost 95% of the patients in our study group. The prevalence of Diabetes was not different among the different severities of CAS. In a study by Taneja et al., Diabetes was present in 60.5% of study subjects. They also observed that 64.3% of patients with mild CAS had Diabetes when compared to 50% with moderate to severe CAS. The difference was not statistically significant like our study. Arifi et al [23] study compared the prevalence of Diabetes between patients with severe CAS (>75%) and no CAS and observed that 77% had diabetes with CAS when compared to 60% in patients with no CAS. Birincioglu et al study compared various study parameters between patients with <60% and >60% CAS. They observed that the prevalence of diabetes in <60% CAS group was 17%

when compared to 12.8% in study subjects with >60%.

In our study, hypertension was present in 75% of study subjects. The prevalence of Hypertension was more in severe CAS when compared to mild CAS (91% vs 74%), though the difference was not statistically significant. In accordance to our results, few other studies also observed similar results. Arifi et al., observed the prevalence of hypertension among patients with severe CAS was 79.5% when compared to only 60% in patients without CAS.

Dyslipidemia was found in around 52% of the participants in our study. There was no significant variation in dyslipidemia prevalence amongst CAS severity levels. Taneja et al. observed that 15 (39.5%) of the 38 patients with CAS had dyslipidemia, compared to 20 (20%) of the patients with normal carotid vessels. The occurrence of dyslipidemia was noted to be substantially associated with degree of stenosis (P=0.000). 10 (35.7%) of the 28 cases with mild CAS had dyslipidemia, while 5 (50%) of the 10 patients with moderate to severe CAS had dyslipidemia.

The history old Stroke was present in 17 patients (10%) in our study group. We observed an increased prevalence of stroke as the severity of CAS increases. Among the patients with mild CAS, 8.9% had old stroke, moderate CAS, 11% had old stroke, however in severe CAS 18% had previous history of stroke. Arifi et al. also observed that, among the patients with severe CAS 12.4% had old stroke when compared to only 3.4% had stroke in patients with no CAS.

Length of hospital stay

In our study, the mean length of hospital stay was 8.97 days. Patients with mild, moderate, and severe CAS had nearly identical lengths of hospital stay. Dworschaf et al study found no difference in length of stay between patients with and without CAS (10 versus 12 days). In contrast, Arifi et al study observed that patients with severe CAS had a longer length of hospital stay than those without CAS. This disparity could be explained by the fact that they compared individuals with severe CAS to patients without CAS. In our study, all of the patients had some degree of CAS, and we compared different degrees of CAS severity.

Atrial Fibrillation (AF)

AF was found in 28 individuals (16.4%) after surgery. AF was observed in 13% of mild CAS patients and 30% of moderate CAS patients. Arifi et al. discovered that 29% of individuals with CAS developed AF, compared to just 16% of patients without CAS.

On pump / Off pump CABG

Overall, patients had On Pump CABG and Off Pump CABG, which were not statistically different. The risk of stroke was not statistically different between the two groups. Similar to our findings, Raja SG et al. and Santarpino et al. studies found no significant difference in the incidence of stroke between patients who underwent On Pump and Off Pump CABG. However, in a major prospective study that spanned 30 years and included around 45000 patients who underwent CABG, it was demonstrated that patients who underwent Off Pump CABG had a lower risk of stroke than those who got On Pump CABG. This divergence from our observation could be attributed to the huge sample size.

Carotid Artery Stenosis

In our study, out of 422 patients who underwent CABG during the study period, 170 had CAS, with a prevalence of 40.2%. In another similar study by Taneja et al., 100 patients were evaluated for the presence of CAS before CABG. Out of 100, CAS was present in 38 patients. Out of 170 patients with CAS, majority, 123 (72.4%) had mild (<50%) stenosis. Moderate (51-69%) stenosis was present in 36 (21.2%) and severe degree (>70%) of stenosis was present in 11 (6.5%).

Özyalçın et al. [21] study observed that 8 (1.1%) patients had stroke following CABG.

In a study published by Kara H et al. [24], 166 patients had carotid artery duplex ultrasonography prior to CABG, among them, 74 had no CAS and the remaining 92 had CAS. Among these 92 patients with CAS, 56 (60.8%) had Mild (20-49%) CAS, 28 (30.4%) had moderate (50- 69%) CAS and 6 (6.5%) patients had severe (≥ 70-99% CAS). The prevalence of different severity grades of CAS in this study was almost similar to our study.

In another similar study by Taneja et al., 100 patients were prospectively evaluated for the presence of CAS before CABG. Out of 100, CAS was present in 38 patients. Of these 38 patients, mild CAS was present in 28 (73.6%) and moderate/severe CAS was present in 10 (26.3%) patients.

In our study, Unilateral CAS was present in majority of the patients, 121(71.2%) and 48 (28.8%) patients had Bilateral CAS. Presence of Unilateral or Bilateral CAS was also evaluated by few studies in the literature. In a study by Hirotani T et al., 62 out of 462 patients had CAS. Of them, 47 (75.8%) had unilateral CAS and 15 (24.1%) had bilateral CAS. In another study by Taneja et al., Out of 100, CAS was present in 38 patients. Of them, unilateral CAS was present in 19 (50%) and bilateral CAS was present in 19 (50%) patients.

Clinical Stroke

Clinical stroke was observed in only 2 patients with an overall risk of 1.17%. In our study, of the 2 patients with stroke, one had moderate CAS, and another had severe CAS. There was no incidence of stroke in mild CAS group. However, amongst the 36 patients with moderate CAS, 1 had stroke (2.7%) and 11 patients with severe CAS, 1 had stroke (9%).

Patients in group 4 had a considerably greater stroke rate than the other three groups. None of the patients with carotid endarterectomy developed stroke. Both patients with Stroke had bilateral CAS in our study. Among the 49 patients with severe CAS, 2 had Stroke with a risk of 4%.

Hence, the risk of stroke was almost doubled in patients with bilateral stenosis when compared to unilateral stenosis.

Post-surgery stroke had significant correlation with previous history of stroke (p=0.001), Severity of carotid artery disease (p=0.01) and bilateral carotid artery disease (p=0.02). Intraoperative factors did not show any significant relation to post surgery stroke. Post-operative low volume state requiring prolonged ionotropic support (p=0.02) showed significant correlation to stroke.

Limitations:

The association of CABG with stroke was mostly observational and may be confounded by unmeasured covariables. The contribution of individual risk factors could be better studied in a prospectively designed study, following young patients in a long-term pattern. Multivariate regression analysis may have the impact of individual factors.

In this study, because the occurrence of stroke was low, and was underpowered to detect significant differences. A larger sample size or a multicenter study with an increased sample size would likely have a greater number of strokes and help estimate the significant of individual factors. No patient underwent carotid artery stenting, or staged carotid revascularization.

Additionally we were unable to determine whether the stroke was embolic or thrombotic and the timing of stroke as only after coming out the mechanical ventilation we could asses the patient.

Results from a single medical center may not be generalizable. A multicentric study with a larger sample size, wider variety of patients and spectrum of carotid disease /stenosis would validate the findings from this study and therefore the applicability and generalizability of the findings.

CONCLUSION

Comorbidities did not show any significant correlation with severity of Carotid artery stenosis. Post-surgery stroke had significant correlation with previous history of stroke, Severity of carotid artery disease and bilateral carotid artery disease. Hence the screening of patients for carotid artery disease in special circumstances age >65 years with previous stroke, and comorbidities aids the surgeon to take required measures to prevent stroke as a complication intraoperative or postoperative and decrease morbidity to the patient

Conflict of interest: none declared
Financial support: none declared

REFERENCES

1. Prasad K. Pathophysiology and medical treatment of carotid artery stenosis. *Int J Angiol.* 2015 Jun 23:158-72. doi: 10.1055/s-0035-1554911.
2. Brinjikji W, Huston J, Rabinstein AA, Kim GM, Lerman A, Lanzino G. Contemporary carotid imaging: from degree of stenosis to plaque vulnerability. *J Neurosurg.* 2016 Jan 1;124(1):27-42. doi: 10.3171/2015.1.JNS142452.
3. Jinnouchi H, Sato Y, Sakamoto A, Cornelissen A, Mori M, Kawakami R, et al. Calcium deposition within coronary atherosclerotic lesion: Implications for plaque stability. *Atherosclerosis*. 2020 Aug 1;306:85-95. doi: 10.1016/j.atherosclerosis.2020.05.017.
4. Shi X, Gao J, Lv Q, Cai H, Wang F, Ye R, Liu X. Calcification in atherosclerotic plaque vulnerability: friend or foe?. *Front Physiol.* 2020 Feb 5;11:56. doi: 10.3389/fphys.2020.00056.
5. Vancheri F, Longo G, Vancheri S, Henein M. Coronary Microcalcification. In: Henein M (eds). Cardiovascular Calcification. Springer, Cham. 2022. doi: 10.1007/978-3-030-81515-8_9.
6. Giannopoulos S, Texakalidis P, Charisis N, Jonnalagadda AK, Chaitidis N, Giannopoulos S, et al. Synchronous carotid endarterectomy and coronary artery bypass graft versus staged carotid artery stenting and coronary artery bypass graft for patients with concomitant severe coronary and carotid stenosis: a systematic review and meta-analysis. *Ann Vasc Surg.* 2020 Jan 1;62:463-73. doi: 10.1016/j.avsg.2019.06.018.
7. Işık M, Velioğlu Y. Contribution of current comorbid conditions to carotid artery stenosis in patients undergoing coronary artery bypass and stroke distribution in carotid artery stenosis groups. InHeart Surgery Forum. 2021 Aug 25;24(4):E724-E730. doi: 10.1532/hsf.3945.
8. Masabni K, Sabik JF 3rd, Raza S, Carnes T, Koduri H, Idrees JJ, et al. Nonselective carotid artery ultrasound screening in patients undergoing coronary artery bypass grafting: Is it necessary? *J Thorac Cardiovasc Surg.* 2016;151(2):402–8. doi: 10.1016/j.jtcvs.2015.09.108.
9. Gokaldas R, Singh M, Lal S, Benenstein RJ, Sahni R. Carotid stenosis: from diagnosis to management, where do we stand?. *Curr Atheroscler Rep*. 2015 Feb;17:1-8. doi: 10.1007/s11883-014-0480-7.
10. Gaudino M, Rahouma M, Di Mauro M, Yanagawa B, Abouarab A, Demetres M, et al. Early versus delayed stroke after cardiac surgery: a systematic review and meta-analysis. *Am Heart J.* 2019 Jul 2;8(13):e012447. doi: 10.1161/JAHA.119.012447.
11. Jonsson K, Barbu M, Nielsen SJ, Hafsteinsdottir B, Gudbjartsson T, Jensen EM, et al. Perioperative stroke and survival in coronary artery bypass grafting patients: a SWEDEHEART study. *Eur J Cardiothorac Surg.* 2022 Oct 1;62(4):ezac025. doi: 10.1093/ejcts/ezac025.
12. Ko SB. Perioperative stroke: pathophysiology and management. *Korean J Anesthesiol*. 2018 Feb 1;71(1):3-11. doi: 10.4097/kjae.2018.71.1.3.

13. Somnuke P, Kattiyawittayakul K, Wongyingsinn M, Raksakietisak M. Incidence, risk factors and outcomes of early post-operative stroke in a university-based, tertiary care hospital: A 7-year retrospective case-control study. *Medicine*. 2023 Jul 14;102(28):e34363. doi: 10.1097/MD.0000000000034363.
14. Benesch C, Glance LG, Derdeyn CP, Fleisher LA, Holloway RG, Messé SR, et al.; American Heart Association Stroke Council; Council on Arteriosclerosis, Thrombosis and Vascular Biology; Council on Cardiovascular and Stroke Nursing; Council on Clinical Cardiology; and Council on Epidemiology and Prevention. Perioperative neurological evaluation and management to lower the risk of acute stroke in patients undergoing noncardiac, nonneurological surgery: a scientific statement from the American Heart Association/American Stroke Association. *Circulation*. 2021 May 11;143(19):e923-46. doi: 10.1161/CIR.0000000000000968.
15. Gaudino M, Benesch C, Bakaeen F, DeAnda A, Fremes SE, Glance L, et al; American Heart Association Council on Cardiovascular Surgery and Anesthesia; Stroke Council; and Council on Cardiovascular and Stroke Nursing. Considerations for reduction of risk of perioperative stroke in adult patients undergoing cardiac and thoracic aortic operations: a scientific statement from the American Heart Association. *Circulation*. 2020 Oct 6;142(14):e193-209. doi: 10.1161/CIR.000000000000088.
16. Saxena A, Ng EY, Lim ST. Imaging modalities to diagnose carotid artery stenosis: progress and prospect. *Biomed Eng Online.* 2019 Dec;18:1-23. doi: 10.1186/s12938-019-0685-7.
17. Squizzato F, Spertino A, Lupia M, Grego F, Gerosa G, Tarantini G, et al. Prevalence, risk factors, and clinical effect of coronary artery disease in patients with asymptomatic bilateral carotid stenosis. *J Vasc Surg.* 2023 Apr 1;77(4):1182-91. doi: 10.1016/j.jvs.2022.11.063.
18. Raffa GM, Agnello F, Occhipinti G, Miraglia R, Lo Re V, Marrone G, et al. Neurological complications after cardiac surgery: a retrospective case-control study of risk factors and outcome. *J Cardiothorac Surg*. 2019 Jan 25;14(1):23. doi: 10.1186/s13019-019-0844-8.
19. Ruka E, Lesur O, Gingras M, Buruian M, Voisine E, Marzouk M, et al. Relationship Between the Degree of Carotid Stenosis and the Risk of Stroke in Patients Undergoing Cardiac Surgery. *Can J Cardiol.* 2022 Mar 1;38(3):347-54. doi: 10.1016/j.cjca.2021.11.007.
20. Taneja S, Chauhan S, Kapoor PM, Jagia P, Bisoi AK. Prevalence of carotid artery stenosis in neurologically asymptomatic patients undergoing coronary artery bypass grafting for coronary artery disease: Role of anesthesiologist in preoperative assessment and intraoperative management. *Ann Card Anaesth.* 2016 Jan-Mar;19(1):76-83. doi: 10.4103/0971-9784.173024.
21. Özyalçın S, Diken Aİ, Yalçınkaya A, Türkmen U. Carotid artery stenosis in asymptomatic patients undergoing coronary artery bypass grafting: who and when should be screened?. *Kardiol Pol* (Polish Heart Journal). 2021;79(1):25-30. doi: 10.33963/KP.15649.
22. Hess NR, Killic A, Serna-Gallegos DR, Navid F, Wang Y, Thoma F, Sultan I. Effect of untreated carotid artery stenosis at the time of isolated coronary artery bypass grafting. *JTCVS open.* 2021 Sep 1;7:182-90. doi: 10.1016/j.xjon.2021.07.001.
23. Arifi AA, Ahmad M, Van Onselen R, Najm HK. Prevalence and impact of carotid disease in adult Saudi patients undergoing isolated coronary artery bypass surgery on early postoperative outcome. *Eur Heart J.* 2014;16(Suppl):44-8. doi: 10.1093/eurheartj/suu021.
24. Kara H. Preoperative carotid duplex scanning in patients undergoing coronary artery bypass grafting. *Braz J Cardiovasc Surg.* 2019 Nov 11;34:581-7. doi: 10.21470/1678-9741-2019-0131.