Research Article

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Evaluation of Relationship of Prior Stroke History with New Stroke After Cardiac Surgery

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Abstract

Objectives: In this study, the preoperative stroke history of cardiac surgery cases was investigated. The relationships between previous stroke, vascular distribution areas related to stroke, stroke-related factors, preoperative modified rankin scale (mRs), and postoperative outcomes of patients were researched.

Materials and Methods: From 2013-2021, 3154 patients undergoing cardiac surgery were retrospectively investigated. The study included 106 patients with a preoperative stroke history brain computed tomography and diffusion magnetic resonance images taken.

Results: The preoperative stroke type distribution was 86.8% ischemic stroke, 6.6% transient ischemic stroke, 4.7% hemorrhage and 1.8% subarachnoid hemorrhage. Analysis of patients with preoperative ischemic stroke history (n: 92), indicated significant correlations between the presence of chronic atrial fibrillation ($p=0.01$) and mRs ($p=0.02$) postoperative acute ischemic stroke (AIS) development. Postoperatively, 9.4% developed AIS. The postoperative AIS distribution was 5.5% for off-pump coronary artery bypass grafting (CABG), 9.3% for on-pump CABG, and 15.3% for CABG + valve surgery. In the whole study group and the group with postoperative AIS, the proportions of the duration between previous stroke and surgery were found to be similar. For all patients in the study group, the preoperative mean mRs was 0.61, 0.92 for patients who died, and 1.0 for those who developed postoperative AIS.

Conclusion: As preoperative mRs increased, the number of patients experiencing postoperative stroke increased, and the mean mRs of patients who died postoperatively was higher. Another parameter in determining the correct time between stroke and surgery could be the preoperative mRs score.

Keywords: Stroke, prior stroke, modified rankin scale, coronary artery bypass grafting, cardiac surgery

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Introduction

Stroke occurring after cardiac surgery is a complication resulting in severe consequences. Postoperative stroke is related to long hospitalization duration and increased morbidity and mortality and hence overshadows surgical success. The incidence differs in a variety of studies, with rates of 1.2 to 6% reported after coronary artery bypass grafting (CABG) and 6.5% after CABG + valve surgery[1-8]. Stroke that develops perioperatively and postoperatively was reported to be associated with advanced age, previous stroke, carotid artery stenosis (CAS), peripheral vascular disease, cardiopulmonary bypass (CPB) duration, and postoperative atrial fibrillation (AF)[2,3,9].

There are very few data on the effect of preoperative stroke history, vascular distribution areas, and modified rankin scale (mRs) linked to stroke on the development of stroke after cardiac surgery and outcomes in patients undergoing cardiac surgery. Additionally, the data related to the timing of open-heart surgery after stroke are limited. In this study, cases operated for isolated CABG and additional cardiac reasons in addition to CABG with a preoperative stroke history were investigated. The possible relationships between previous stroke, stroke-related factors, vascular distribution areas related to stroke, preoperative mRs of patients were investigated with the perioperative/postoperative surgical and neurological/vascular data and postoperative mRs of patients developing postoperative stroke.

Materials and Methods

A total of 3154 patients were retrospectively investigated from January 2013 to June 2021 for isolated CABG and other cardiac procedures accompanying CABG, including mitral, aortic, tricuspid, and aortic surgery (on-pump CABG 2288, off-pump CABG 263, CABG + valve 562, CABG + aortic surgery 41). The study included 106 patients with preoperative stroke history, and they had preoperative brain computed tomography (CT) and brain diffusion magnetic resonance imaging (MRI) imaging taken. Cases in which a stroke attack was determined but no cranial imaging related to this stroke was available (11 patients), and cases with a postoperative stroke attack for which no cranial imaging was available (1 patient), were excluded from the study. Additionally, the study did not include patients undergoing surgery in emergency conditions nor those developing stroke after discharge. The study design is given in Figure 1.

Patients with preoperative ischemic stroke (n: 92) were additionally categorized to research the effect of: age, sex, surgery type, aortic clamping time (ACT), mortality, AF, ejection fraction (EF), preoperative mRs, stroke vascular distribution area, duration between previous stroke and surgery, and comorbid status diabetes mellitus (DM) hypertension (HT), DM+HT, body mass index (BMI), end-stage renal disease (ESRD)] on postoperative stroke development.

During admission, all patients had their general medical history taken, underwent physical and neurological examinations, had standard laboratory tests, and had a 12-derivation electrocardiogram taken. Stroke was defined as rapidly developing temporary/permanent focal neurological symptoms and the presence of symptoms of vascular origin. Patients with suspected postoperative stroke had stroke diagnosis confirmed clinically and radiologically using non-contrast CT and diffusion-weighted MRI. All data related to previous stroke and postoperative stroke attack were determined by a neurologist. Information related to patients was obtained from the hospital software system, medical records, doctor monitoring notes, and the national health system database. Written informed consent was obtained from patients for the surgical procedure. The study protocol for our retrospective study was approved by the Necmettin Erbakan University Non-Medicine and Medical Device Research Ethics Committee (approval no.: 2021/3381, date: 03.09.2021). The work has been prepared in accordance with the Declaration of Helsinki. No artificial intelligence was used in any process of the article.

The lesion site of the stroke was determined with radiological findings and the vascular distribution area of the stroke was classified as follows; A total anterior circulation infarct (TACI) is a large cortical stroke affecting the areas of the brain supplied by both the middle and anterior cerebral arteries. A partial anterior circulation infarct (PACI) is a less severe form of TACI, in which only part of the anterior circulation is compromised. A posterior circulation infarct (POCI) involves damage to the area of the brain supplied by the posterior circulation. A lacunar infarct (LACI) is a subcortical stroke that occurs secondary to small vessel disease[10]. Border zones are areas that lie at the junction of two different drainage areas. Border zone infarcts (BZI) are ischemic lesions that occur in characteristic locations at the junction between two main neighboring arterial territories[11]. Multiple territorial infarcts (MTI) are traditionally defined on neuroimaging as non-contiguous infarcts located in more than one cerebral circulation[12].

Patients with a preoperative stroke history, as well as those developing a postoperative stroke, had their mRs determined with the mRS. mRS is a scale commonly used to measure the degree of disability or dependence in daily activities of people with stroke or other neurological disabilities. The scale has points from 0 to 6: 0 means no symptoms; 1, no significant disability, able to perform all normal activities in spite of some symptoms; 2, mild disability, able to look after their needs without assistance but unable to complete all previous activities; 3, moderate disability, requires some help but can walk without aid; 4, moderate to severe disability, cannot meet bodily needs without aid and cannot walk; 5, severe disability, requires continuous nursing care, bedridden, incontinent; and 6, death[13].

Surgical Technique

In on-pump cases, an aortic cross-clamp was used, and cardioplegia was administered. After performing a proximal anastomosis on the heart, side clamping was applied. For all isolated CABG cases, the left anterior descending artery (LAD) was bypassed by the left internal mammary artery (LIMA). For CABG + valve cases, if the

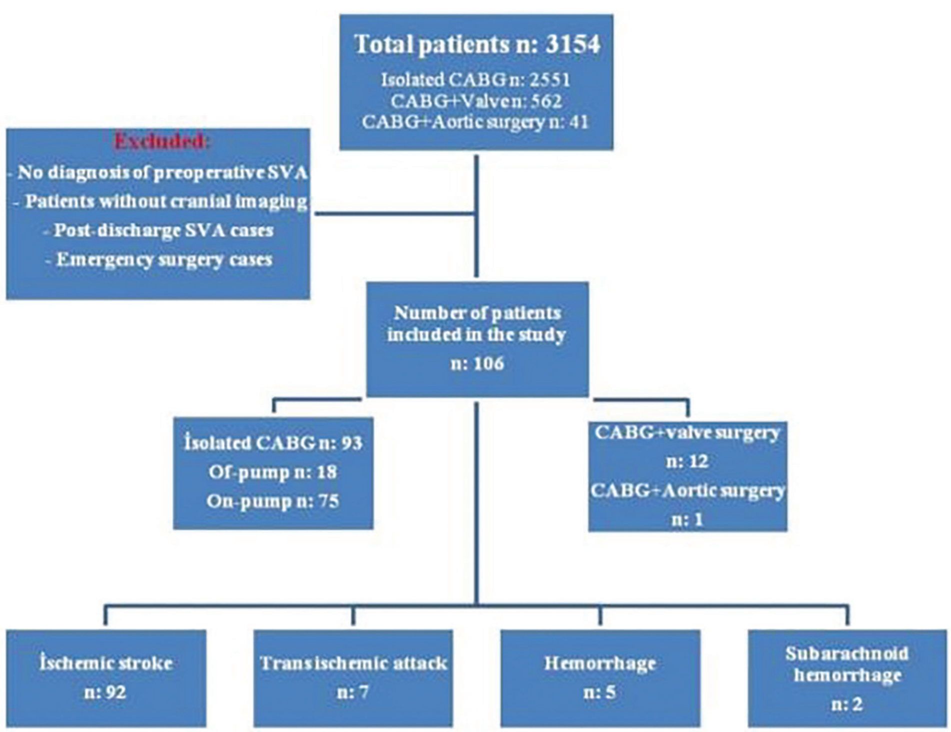

Figure 1. Study design

SVA: Cerebrovascular accident, CABG: Coronary artery bypass grafting

LAD did not require bypass, the LIMA was not used. For circumflex and right CAB, the saphenous vein was used. For off-pump CABG, side clamp wasused for proximal anastomosis of grafts apart from LIMA. Other surgeries were completed with standard CPB procedures.

Statistical Analysis

Descriptive statistics are given for all variables. Numerical variables are given as mean and standard deviation, while nominal variables are shown as frequency and percentage. The t-test was used for the analysis of numerical variables. The chi-square test and logistic regression analysis were used to analyze nominal variables. The analyses used SAS University Edition 9.4 program (SAS Institute, Cary NC), and a p-value of less than 0.05 was accepted as significant.

Results

Of patients, 75.4% were male and 24.5% were female. Mean age was 66.6 years (range: 33-86). Mean ACT was 64.2 minutes (25-181), mean BMI was 28.2 kg/m² (20.3-43), mean EF was 51.5% (25-60), preoperative mean mRs was 0.61 (0-4), mean discharge duration was 9.2 days (4-30), and mean exitus duration was 7.2 days (0-28). Of the cases, 86.7% were discharged, and 13.2% were deceased. The demographic distribution and detailed information related to surgery are given in Table 1.

The distribution of preoperative stroke type was 86.7% (n: 92), ischemic stroke, 6.6% (n: 7), transient ischemic attack (TIA), 4.7% (n: 5), intracerebral hemorrhage, and 1.8% (n: 2), subarachnoid hemorrhage Supplementary material 1. Detailed information for patients with preoperative ischemic stroke is given in Table 2. Postoperatively, 10 patients (9.4%) developed acute ischemic stroke (AIS). Detailed information about these patients is given in Table 3. Patients with preoperative TIA, hemorrhage, and subarachnoid hemorrhage did not experience any new neurological event postoperatively. Additionally, no patient was observed to newly develop TIA, hemorrhage, and subarachnoid hemorrhage postoperatively.

As a result of statistical analysis of patients with preoperative ischemic stroke history (n=92), the postoperative AIS development rate was high among those with chronic AF (p=0.01). A correlation was identified between preoperative mRs value and postoperative AIS development (p=0.02). The presence of ESRD and postoperative AIS development rate were close to significance (p=0.09). The total number of patients with preoperative mRs of 0 and 1 was 78, and 7.6% of these patients developed postoperative AIS. The total number of patients with preoperative mRs of 2, 3 and 4 was 14, and 28.5% of these patients developed postoperative AIS (Figure 2). There were no statistically significant correlations among age, sex, surgery type, EF, mortality, stroke vascular distribution area, duration between previous stroke and surgery, and comorbid status, and postoperative AIS.

Of patients with preoperative ischemic stroke history (n: 92), the duration between previous stroke and surgery was ≤1 month for 7.6%, 1-12 months for 21.7%, and >12 months for 70%. The minimum duration was 15 days, with the maximum duration 240 months. In this group, the PACI case rate was 34.7%, LACI was 32.6%, POCI was 29.3%, BZI was 3.2% and MTI was 0%.

In our study group, 10 patients developed new postoperative AIS. The preoperative neurological event in these patients was ischemic stroke. Two of the patients

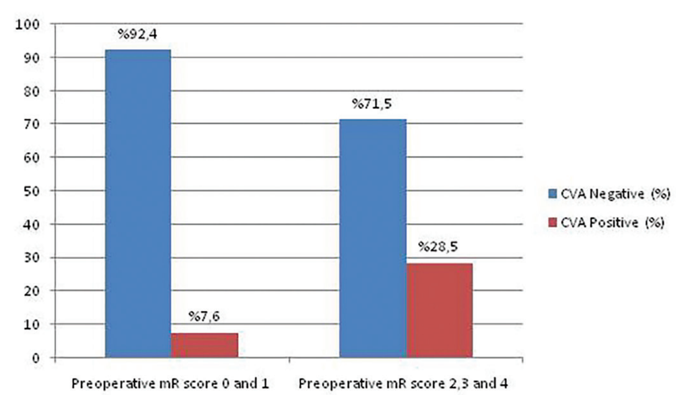

Figure 2. Distribution of patients with postoperative CVA according to preoperative mRs values

CVA: Cerebrovascular accident, mRs: Modified rankin scale

Table 1. Detailed information on demographics of patients and the surgeries performed

Patients data	Details	Numeric data
General information		
Age	<55, 55-69, ≥70	12/51/43
Gender	Male/Female	80/26
Body mass index	<25, 25-29, ≥30	27/43/36
Data on preoperative CVA		
Time between CVA and surgery	≤1 month, 1-12 month, >12 month	11/23/72
CVA type	Stroke, TIA, haemorrhage, subarachnoid	92/7/5/2
mRs	0/1/2/3/4	69/22/8/4/3
Hemisphere distribution	Right, left, bilateral, other regions	34/42/12/11
Additional preoperative data		
Diabetes mellitus	Yes/No	68/38
Hypertension	Yes/No	87/19
Diabetes + hypertension	Yes/No	61/45
Pulmonary disease	Yes/No	14/92
End-stage kidney failure	Yes/No	11/95
Peripheral artery disease	Yes/No	7/99
Carotid stent	Right/left	2/2
Malignity	Colon/Cranial/Leukaemia	1/1/1
Preoperative cardiac data		
Ejection fraction	<30, 30-49, ≥50	2/33/71
Atrial fibrillation	Chronic	8
Perioperative data		
Aorticclamp time (minute)	<50, 50-70, >70	25/37/26
Total pomp duration (minute)	<80, 80-120, >120	18/48/22
Temperature (°C)	29-31/32	8/80
The work of the heart	Spontaneous/Fibrillation	54/34
Cardioplegia type	Custodial/Cold blood	2/86
Cardioplegia path	Antegrade/Antegrade + retrograde	83/5
Autologous blood draw (unite)	0/1/2	73/12/21
Urine amount in CPB (mL)	<300/ >300	40/48
Inotropic agent requirement	Yes/No	82/24
Vasoactive medication use	Yes/No	4/102
IABP need	Yes/No	5/101
End of surgery heart rhythm	Sinus/AF/Pacemaker	94/10/2
Surgery type		
Isolated CABG	On-pump/Of-pump	75/18
CABG + valve surgery	AVR, MVR/MRA, MRA+TRA, MVR+AVR+TRA	3/7/1/1
CABG + aortic surgery	Reoperation AVR + aortic root expansion	1
Postoperative data		
Newly developed AF	In the first 24 hours/After the first 24 hours	6/5
Time to migrate postop new CVA	First 24 hours/24-72 hours/After 72 hours	1/5/4
mRs	0/1/2/3/4/5/6	63/22/9/5/5/0/2
Duration of discharge (day)	<7, 7-14, >14	50/31/11
Time of death (day)	<7, 7-14, >14	9/3/2

CVA: Cerebrovascular accident, mRs: Modified rankin scale, TIA: Trans ischemic attack, CPB: Cardio pulmonary bypass, AF: Atrial fibrillation, IABP: Intra-aortic balloon pump, AVR: Aortic valve replacement, MVR: Mitral valve replacement, MRA: Mitral ring annuloplasty, TRA: Tricuspid ring annuloplasty were female and eight were male. Mean age was 65.5 years (49-77), mean ACT was 77.3 minutes (42-181), mean EF was 51.3% (35-60), mean BMI was 28.8 kg/m^2 (23.6-43), and mean discharge duration was 17.3 days (6-27). In these patients, 90% had HT, 70% DM, 70% DM+HT, 40% chronic AF, and 30% ESRD. The mean preoperative mRs for these 10 patients was 1.0 (0-3), while the mean post-AIS postoperative mRs was 3.5 (2-6). While two patients died, eight were discharged. The duration between previous stroke and surgery was more than 12 months for 7 patients and 1, 3, and 5 months for the others. Mean postoperative AIS development time was 3.3 days (range: 2-7). The first symptom after AIS was consciousness changes in 5 patients, loss of muscle strength in 3 patients, dizziness in 1 patient and vision and balance disorders in 1 patient (Table 3).

Patients developing postoperative AIS had preoperative stroke vascular distribution of 20% PACI, 30% POCI,

Table 2. Data of patients (n: 92) with a preoperative diagnosis of ischemic stroke

	TACI (n: 0)	PACI (n: 32/34.7%)	POCI (n: 27/29.3%)	LACI (n: 30/32.6%)	WTS (n: 3/3.2%)
Age <65 (n: 31)	-	10	11	7	3
Age ≥65 (n: 61)	-	22	16	23	-/-
Gender M/F, (n: 68/24)	-	25/7	19/8	21/9	3/0
Diabetes mellitus (n: 62)	-	19	21	21	1
Hypertension (n: 76)	-	25	24	25	2
Diabetes + hypertension (n: 56)	-	17	19	19	1
Chronic AF (n: 8)	-	4	1	3	-
New AF (n: 10)	-	1	6	3	-
History of CVA time ≤1 month (n: 7)	-	1/	3	3	-
History of CVA time 1-12 month (n: 20)	-	6	6	8	-
History of CVA >12 month (n: 65)	-	25	18	19	3
EF <50% (n: 30)	-	11	11	7	1
EF ≥50% (n: 62)	-	21	16	23	2
BMI <25 (n: 23)	-	9	8	5	1
BMI 25-30 (n: 37)	-	15	10	11	1
BMI >30 (n: 32)	-	8	9	14	1
Right hemisphere involvement (n: 32)	-	11	6	14	1
Left hemisphere involvement (n: 38)	-	19	8	10	1
Bilateral involvement (n: 11)	-	2	2	6	1
Other regions involvement (cerebellum, brainstem, pons) (n: 11)	-	-	11	-	
Discharge (n: 81)	-	25	24	29	3
Death (n: 11)	-	7	3	1	-

TACI: Total anterior circulation infarct, PACI: Partial anterior circulation infarct, POCI: Posterior circulation infarct, LACI: Lacunar infarct, WTS: Watershed infarct, CVA: Cerebrovascular accident, EF: Ejection fraction, AF: Atrial fibrillation, BMI: Body mass index and 50% LACI. The new postoperative AIS vascular distribution for these 10 patients was 10% PACI, 0% LACI, 50% POCI, 20% BZI, and 20% MTI. Three of these patients had the same preoperative and postoperative vascular areas. For the other patients, the preoperative vascular areas were different from the postoperative vascular areas. Two patients had preoperative infarct, with right hemisphere localization, and it remained on the right postoperatively. The infarct hemisphere localization in other patients differed preoperatively and postoperatively. Additionally, while 1 patient had a preoperative bilateral hemisphere lesion, postoperatively, 4 patients were identified to have bilateral hemisphere lesions (Table 3).

Among all patients in the study group, 13.2% (n: 14) died postoperatively. Of these, two were patients who developed postoperative AIS. When the deceased patients are assessed in terms of preoperative stroke type, 60% (n: 3/5) had hemorrhage, 21.8% (n: 7/32) had PACI, 11.1% (n: 3/27) had POCI, and 3.3% (n: 1/30) had LACI. The mean age of deceased patients was 64.5 years (49-86); sex distribution was 14.2% women and 85.7% men. The duration between stroke and surgery for these patients was 3 months for 1 patient (7.1%), and more than 12 months for the other 13 patients (92.8%). The preoperative mean mRS for deceased patients was 0.92 (9 patients had mRS 0, 2 patients had mRS 3, and 1 patient each had mRS 1, 2, and 4). Causes of death were multiorgan failure for 42%, low cardiac output for 28%, and sepsis for 28%.

Discussion

One of the most important results of the study is that as the preoperative mRs score increased, so did the percentage of patients developing postoperative stroke, with 7.6% of patients with preoperative mRs 0 and 1,

Table 3. Detailed demographic, neurologic, and surgical-related information on patients with postoperative re-CVA

A/G	BMI	Co-morbidity	CS % right/left	AF	EF (%)	Surgery type	ACT	Heart work	Preop CVA/ month	Postop CVA/ time	Preop mRs	Postop mRs	Preop hemisp	Postop hemisp
67/M	35.2	DM, HT, ESRD	100/50	-	40	Cx2	43	SS	PACI/ 36	POCI/ 2th day	0	2	Right	Right
67/M	26.3	HT	N	-	55	Cx4	59	SS	LACI/ 60	POCI/ 2th day	2	4	Right	Bilateral
71/M	25.1	HT	-	Cr	60	Cx4	53	SS	LACI/ 5	WTS/ 4th day	0	4	Right	Right
72/M	26.5	DM, HT	Atherosc	-	55	Cx3	42	SF	POCI/ 122	MTS/ 3th day	0	2	Left	Bilateral
77/M	43	DM, HT, ESRD	-	-	45	Cx3	45	SS	LACI/ 1	MTS/ 7th day	3	3	Right	Bilateral
68/M	25.6	DM, HT	Atherosc	-	55	Cx3	48	SS	LACI/ 84	POCI/ 2th day	0	2	Right	Left
49/M	25.2	DM, HT, ESRD	N	Cr	35	Cx2 off pump	-	-	PACI/ 3	PACI/ 4th day	3	6	Left	Right
72/M	23.6	DM, HT	-	Cr	48	Cx2+M +A*+TR	165	SS	POCI/ 24	POCI/ 2th day	0	6	Bilateral	Pons
51/F	25.9	A*+M	N	Cr	60	Cx1+A**	181	SF	LACI/ 13	WTS/ 4th day	0	3	Right	Bilateral
61/F	31.9	DM, HT	30/25	-	60	Cx4	60	SS	POCI/ 96	POCI/ 3th day	2	3	Left cerebellar	Right cerebellar

A: Age, G: Gender, BMI: Body mass index, CS: Carotid stenosis, AF: Atrial fibrillation, EF: Ejection fraction, ACT: Aortic clamp time, CVA: Cerebrovascular accident, Preop CVA/month: Time from ex CVA to surgery, mRs: Modified Rankin scoring, Hemisp: Hemisphere, DM: Diabetes mellitus, HT: Hypertension, ESRD: End-stage renal disease, C x number: CABG and number of bypasses, SS: Spontaneous study, SF: Study in fibrillation, N: Normal, Cr: Chronic, Atherosc: Atherosclerosis, M: Mitral valve replacement, A: Aortic valve replacement, TR: Tricuspid ring annuloplasty, A**: Reoperation Aortic valve replacement + aortic root enlargement, PACI: Partial anterior circulation infarction, POCI: Posterior circulation infarction, LACI: Lacunar circulation infarction, WTS: Watershed territorial stroke, MTS: Multiple territorial stroke* and 28.5% of patients with preoperative mRs 2, 3, and 4 developing postoperative AIS. There was a statistically significant correlation between preoperative mRs score and postoperative stroke (p=0.02).

The effect of a previous stroke on mRs may extend far beyond the acute phase. In spite of rehabilitation and supportive treatment after stroke, neurological dysfunction continues for many people. Just as post-stroke mRs may be affected by situations like the clinical significance of the stroke, age, comorbidities, lesion site and volume, it may be affected by control of stroke-related risk factors and rehabilitative practices. Studies showed that patients with worse mRs had more serious risks, including death, even after accompanying cardiovascular problems were under control[14]. The results of our study support these data. Of the patients who died postoperatively, the preoperative mean mRS was higher than that of the whole patient group (mean mRS for all patients 0.61, mean mRS for exitus patients 0.92). Additionally, a change in mRs by a single point was reported to cause significant outcomes in terms of survival duration, not just in terms of patient independence[14].

Patients with postoperative AIS in the study group had a mean preoperative mRS of 1.0, and a mean mRS of 3.5 after postoperative AIS, indicating moderately severe disability. Deterioration in mRs disability increases the risk of postoperative complications including death. Additionally, patients with a history of stroke and affected by mRs should have their cerebrovascular reserve assessed for the risk of possible new postoperative stroke. It is clear that the poor preoperative mRs of patients considered to have low cerebrovascular reserve will have negative effects on neurological function postoperatively following another stroke. All these situations reveal the importance of knowing the preoperative mRs. The addition of the mRs scale to the EuroSCORE rating system, used for cardiac risk scoring, may be more beneficial for determining surgical risk, (at the moment evaluation is just neurological dysfunction present/absent).

The literature does not provide a satisfactory answer about when surgery should be performed after stroke. A study by Bottle et al.[15] reported that the time interval between previous stroke and surgery did not increase postoperative stroke, mortality, and hospitalization duration. Rorick and Furlan[16] stated that patients with a recent stroke (<3 months) have a higher probability of increased stroke-related lesions in the postoperative period, however, patients with a history of stroke (>3 months) had a higher probability of lesions associated with a new stroke. Matthews et al.[17] classified stroke history as "recent (stroke within 2 weeks before surgery), intermediate (greater than 2 weeks but less than 6 weeks before), and remote (greater than 6 weeks before)" and stated that the timing of cardiac surgery after stroke did not appear to affect postoperative stroke or mortality. Additionally, they reported that mortality associated with stroke was higher, if new postoperative stroke occurred in these patients. The results of our study did not identify associations between the interval between previous stroke and surgery, postoperative AIS, stroke vascular area, mRs, mortality, and hospitalization duration. In the whole study group, as well as in the patient group with postoperative AIS, the proportions for durations between previous stroke and surgery were similar. The percentage of patients with less than 1 month between the previous stroke and surgery was nearly 10%, while for 70%, the duration was more than 12 months.

On a different point, studies to date provide inadequate data about whether the etiology of previous stroke plays a role. For example, stroke in patients with infective endocarditis may be linked to septic embolization, different in nature from stroke in patients with atherosclerotic vascular and coronary artery disease. At this point, the etiopathogenesis in patients with a history of stroke becomes especially important. For this reason, we think the accurate duration between stroke and surgery should be revealed by adequate documentation of preoperative variables, including details related to stroke history (etiopathogenesis of previous stroke, severity, localization and volume of stroke, and available cerebrovascular reserve). It is important to note that within 30 to 90 days after discharge due to a previous stroke, 2/3 of patients experience significant changes in mRs scores (1/3 worsen, 1/3 improve, and 1/3 do not change)[18]. This data indicate that mRs in the nearly three-month period after stroke may negatively affect postoperative outcomes. Considering our data related to preoperative mRs, we think another parameter to determine the accurate duration between stroke and surgery may be the preoperative mRs score of patients.

One of the notable results of the study is that among those with preoperative ischemic stroke history (n: 92), 32% had LACI, while among patients with postoperative AIS (n: 10), 50% had LACI. None of the postoperative AIS patients had new LACI identified, with this group having 50% POCI, 20% BZI, 20% MTI, and 10% PACI. Occlusion or blockage of the small penetrating arteries causes small infarcts called lacunar strokes. Posterior circulation strokes account for approximately 20-25% of all strokes. It is stated that approximately 24% of POCI are associated with cardiac-origin emboli, while 32-35% are associated with atherosclerotic large vessel disease. BZI may be better explained by invoking a combination of two often interrelated processes: hypoperfusion and embolization. Hypoperfusion, or decreased blood flow, is likely to impede the clearance (washout) of emboli. Because perfusion is most likely to beimpaired in border zone regions, clearance of emboli will be most impaired in these regions withleast blood flow. Additionally, stenotic disease of the internal carotid artery causes both embolization and decreased perfusion. Similarly, cardiac disease is often associated with microembolization from the heart and aorta, with periods of diminished systemic and brain perfusion. Isolated cortical BZI may be embolic in nature and are less frequently associated with hemodynamic compromise. Micro emboli from the heart or atherosclerotic plaques in major arteries may preferentially propagate to cortical border zones, which have lower perfusion than other areas of the vasculature and thus limited ability to wash out these emboli[19,20].

When the literature information is assessed with the results of our study, the relationship between hypoperfusion and/or embolization as possible pathophysiological mechanisms of postoperative stroke is confirmed. In our previous study, a nearly 77.5% rate of postoperative POCI, BZI, and MTI were identified[21]. All this data indicate, that, especially for patients with a stroke history, assessment of cerebrovascular reserve in terms of the probable pathophysiological mechanisms mentioned, due to possible postoperative stroke risk, will provide serious positive contributions to decisions related to the form, type, and duration of the operation to be performed.

In our clinic, patients without any complications were discharged on the 5th postoperative day, while the mean discharge time for patients in the study group was found to be 9.2 days. In addition, in another study we conducted previously, the mean hospital stay for patients who underwent postoperative AIS was found to be 16 days[21]. In the literature, similar to our results, it has been reported that the postoperative hospital stay is prolonged in patients with a history of preoperative stroke who underwent cardiac surgery, and the probability of recurrence of stroke increases[7,15], reaching rates of 7.8%-12.4%[21,16].

It has been reported that hypotension is a potential risk factor for perioperative stroke in patients undergoing CPB and may also be an important intraoperative therapeutic hemodynamic target to reduce the incidence of stroke[6]. In addition, keeping arterial pressure high during CPB in patients with CAS may be a strategy to prevent cerebral hypoperfusion. It has been reported that as CAS rates increase in patients undergoing cardiac surgery, the incidence of stroke increases (CAS 2.1% in the 0-29% group, 2.5% in the 30-49% group, 4.5% in the 50-69% group, and 11.1% in the 70-99% group)[2]. During aortic clamping, blood flow is non-pulsatile and arterial blood pressure values are below normal physiological limits. Intracranial vascular stenosis or the presence of CAS and prolonged ACT may increase the likelihood of stroke.

Study Limitations

There are some limitations to this single-center retrospective study. Firstly, the relatively small sample size may limit the strength and clarity of significant correlation results. Secondly, there was a lack of extracranial vascular imaging for all patients developing postoperative AIS, and the carotid artery reserves were not known. Thirdly, this study included patients undergoing surgery for isolated CABG and other cardiac causes accompanying CABG. It is not possible for the findings to encompass all cardiac surgeries.

Conclusion

As preoperative mRs score increased, the number of patients experiencing postoperative stroke increased and the mean mRs of patients who died postoperatively was higher. Our study shows that another parameter that can be used to determine the correct duration between stroke and surgery is the preoperative mRs score.

Ethics

Ethics Committee Approval: The study protocol for our retrospective study was approved by the Necmettin Erbakan University Non-Medicine and Medical Device Research Ethics Committee (approval no.: 2021/3381, date: 03.09.2021). The work has been prepared in accordance with the Declaration of Helsinki.

Informed Consent: Written informed consent was obtained from patients for the surgical procedure.

Footnotes

Authorship Contributions

Surgical and Medical Practices: Işık M, Concept: Işık M, Kozak HH, Design: Işık M, Kozak HH, Data Collection and/or Processing: Işık M, Kozak HH, Analysis and/or Interpretation: Işık M, Kozak HH, Literature Search: Işık M, Kozak HH, Writing: Işık M, Kozak HH.

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Supplement Material 1. Data on patients (n: 14) with a diagnosis of CVA other than preoperative ischemic stroke

	Haemorrhage (n: 5)	Subarachnoid (n: 2)	TIA (n: 7)
Age <65 (n: 5)	2	1	2
Age ≥65 (n: 9)	3	1	5
Gender (F/M, n: 12/2)	5/-	2/-	5/2
DM (n: 6)	1	1	4
HT (n: 11)	3	2	6
DM+HT (n: 5)	-	1	4
Chronic atrial fibrillation (n: 0)	-	-	-
New atrial fibrillation (n: 1)	1	-	-
History of CVA time ≤1 month (n: 4)	-	-	4
History of CVA time 1-12 month (n: 3)	-	-	3
History of CVA >12 month (n: 7)	5	2	-
EF <%50 (n: 5)	2	-	3
EF ≥%50 (n: 9)	3	2	4
BMI <25 (n: 4)	2	1	1
BMI 25-30 (n: 6)	3	-	3
BMI >30 (n: 4)	-	1	3
Isolated CABG	5	2	7
CABG + Valve	-	-	-
Right hemisphere involvement (n: 2)	2	-	-
Left hemisphere involvement (n: 4)	3	1	-
Bilateral hemisphere involvement (n: 1)	-	1	-
Discharge (n: 11)	2	2	7
Death (n: 3)	3	-	-

TIA: Trans ischemic attack, DM: Diabetes mellitus, HT: Hypertension, CVA: Cerebrovascular accident, EF: Ejection fraction, BMI: Body mass index