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Journal
Stroke, 53(1)

ISSN
0039-2499

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Publication Date
2022

DOI
10.1161/strokeaha.120.032410

Peer reviewed

HHS Public Access
Author manuscript
Stroke. Author manuscript; available in PMC 2023 June 16.

Published in final edited form as:
Stroke. 2022 January ; 53(1): 100–107. doi:10.1161/STROKEAHA.120.032410.

In-hospital Outcomes of Urgent, Early or Late Revascularization for Symptomatic Carotid Artery Stenosis

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Abstract

Background and Purpose: Advancements in carotid revascularization have produced promising outcomes in patients with symptomatic carotid artery stenosis. However, the optimal timing of revascularization procedures after symptomatic presentation remains unclear. The purpose of this study is to compare in-hospital outcomes of transcarotid artery revascularization (TCAR), transfemoral carotid stenting (TFCAS) or carotid endarterectomy (CEA) performed within different time intervals after most recent symptoms.

Methods: This is a retrospective cohort study of United States patients in the Vascular Quality Initiative. All carotid revascularizations performed for symptomatic carotid artery stenosis between September 2016-November 2019 were included. Procedures were categorized as urgent (0–2 days after most recent symptom), early (3–14 days) or late (15–180 days). The primary outcome of interest was in-hospital stroke and/or death. Secondary outcomes include in-hospital stroke, death, and transient ischemic attacks. Multivariable logistic regression was utilized to compare outcomes.

Results: A total of 18,643 revascularizations were included: 2006(10.8%) urgent, 7,423(39.8%) early, and 9,214(49.42%) late. TFCAS patients had the highest rates of stroke/death at all timing cohorts (Urgent: 4.0% CEA, 6.9% TFCAS, 6.5% TCAR, p=0.018; Early: 2.5% CEA, 3.8% TFCAS, 2.9% TCAR, p=0.054; Late: 1.6% CEA, 2.8% TFCAS, 2.3% TCAR, p=0.003). TFCAS also had increased odds of in-hospital stroke/death compared to CEA in all three groups [Urgent aOR:1.7, 95%CI:1.0–2.9, p=0.03], [Early aOR:1.6 (95%CI:1.1–2.4), p=0.01], [Late aOR:1.9 (95%CI:1.2–3.0), p=0.01]. TCAR and CEA had comparable odds of in-hospital stroke/death in all three groups [Urgent aOR:1.9, 95%CI:0.9–4, p=0.10], [Early aOR:1.1, 95%CI:0.7–1.7, p=0.66], [Late aOR:1.5, 95%CI:0.9–2.3, p=0.08].

Conclusion: CEA remains the safest method of revascularization within the urgent period. Among revascularization performed outside of the 48-hours, TCAR and CEA have comparable outcomes.

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Keywords

timing; urgent; TFCAS; TCAR; carotid stenosis; carotid endarterectomy; carotid artery stenting

Subject Terms

Quality and Outcomes; Revascularization; Stenosis; Treatment; Vascular Disease

Introduction

Surgical intervention is superior to medical management for the treatment of symptomatic carotid artery stenosis.[1] Early intervention can prevent recurrent stroke or transient ischemic attack (TIA), which may be as high as 20% in the first 72 hours after onset of symptoms.[2] Early intervention is also associated with long-term benefits. In a pooled analysis of over 2000 patients from the North American Symptomatic Carotid Endarterectomy Trial and the European Surgical Carotid Trial, patients receiving carotid endarterectomy (CEA) within two weeks of onset of symptoms had 19% absolute risk reduction in the risk of recurrent stroke.[3] However, CEA benefits decreased when intervention was delayed. Patients undergoing revascularization at 12 weeks or later after the onset of symptoms had no demonstrable benefit.

Despite the desire to perform early revascularization, evidence suggests that CEA within 48-hours of symptoms is associated with increased perioperative risks. In a study from the Swedish National Registry, patients undergoing CEA within 48 hours had 4 times the odds of 30-day stroke or death when compared to patients undergoing CEA between 3–7 days.[4] Similar results were noted in the National Vascular Registry of the United Kingdom,[5] smaller retrospective studies,[6] and other prospective registries.[7] Outside of this 48-hour window, however, early and delayed revascularization, either at 7-days or 14-days, had comparable safety profiles. Given that the perioperative risks of performing CEA between 3 and 14 days after symptoms are relatively low compared to the risk of recurrent stroke, revascularization after 48 hours from the onset of symptoms may represent ideal timing for carotid revascularization. Current guidelines from the Society of Vascular Surgery and the European Society of Vascular Surgery recommend CEA within two weeks for patients presenting with mild or moderate neurologic deficits.[8,9]

Most studies on timing of carotid revascularization for symptomatic patients have focused on CEA. In general, transfemoral stenting (TFCAS) has higher perioperative stroke risk when compared to CEA.[10] Studies on TFCAS timing have found that this elevated perioperative risk is more pronounced within the immediate time period after onset of symptoms. A study from the Carotid Stenosis Trialists' Collaboration combining data from four large randomized clinical trials found that TFCAS has anywhere between 6–8 times higher periprocedural risk within the first seven days after symptoms compared to 2-times higher periprocedural risk in procedures delayed beyond seven days.[11] These findings led to CEA being considered the recommended intervention for early symptoms.[8]

A novel method of carotid artery stenting is transcarotid artery revascularization (TCAR) with flow reversal. While prospective randomized control trials have not been completed, it is thought that TCAR's avoidance of the aortic arch and the use of flow reversal have given TCAR comparative outcomes to CEA and half the perioperative risk of stroke/death when compared to TFCAS.[12–15] To date, no studies have looked the outcomes of all three carotid revascularization procedures when performed at different times after symptoms occur. Given that TCAR overcomes many of the pitfalls seen with TFCAS and utilizes carotid clamping similar to CEA, it is possible that TCAR has comparable timing profiles to CEA. The purpose of this study is to compare perioperative outcomes after TCAR, TFCAS, and CEA among patients undergoing urgent, early, and delayed revascularization for symptomatic carotid artery stenosis.

Methods

The data that support the findings of this study are available from the corresponding author upon reasonable request.

We performed a retrospective analysis of the Society for Vascular Surgery (SVS) Vascular Quality Initiative (VQI) CEA and carotid artery stenting registries. The Vascular Quality Initiative is a national quality improvement registry maintained by the Society for Vascular Surgery, a collection of modules capturing granular clinical information on 12 types of vascular procedures performed in more than 400 centers in North America.[8] The TCAR Surveillance Project (TSP) was initiated to capture and monitor outcomes after TCAR treatment using the carotid stenting registry operated by the Vascular Quality Initiative, which contains information on patients undergoing TCAR and transfemoral carotid artery stenting. The Vascular Quality Initiative also captures CEA procedures widely via a separate registry. Approximately 10% of all patients undergoing CEA in the United States undergo their procedure in a Vascular Quality Initiative center.[9,10]

Procedures performed since the start of the TCAR Surveillance Project (September 2016) to November 2019 were included to ensure contemporary cohorts. Symptomatic status was defined as any patient with stroke, TIA, or amaurosis fugax ipsilateral to the surgery side documented within six months of surgery date. Symptomatic patients comprised 26% of the total cohort. If patients had multiple symptoms recorded, the symptom that was closest to the date of procedure was considered the presenting symptom. Asymptomatic patients, patients receiving intervention for non-atherosclerotic lesions, patients undergoing concomitant procedures and those with more than one treated lesion were excluded from the analysis. (Supplementary Figure I) We also conducted a sensitivity analysis including then excluding patients undergoing intervention for restenotic lesions. The remaining patients were divided into three groups depending on the timing of intervention:

1. Urgent revascularization: between 0–2 days from latest symptom.
2. Early revascularization: between 3–14 days from the latest symptom
3. Late revascularization: between 15–180 days from the latest symptom.

Only deidentified information from participating institutions in VQI was used for this analysis, therefore the need for Institutional Review Board and informed consent is waived for this study.

Outcomes

Outcomes between TCAR, TFCAS, and CEA were compared within each of the timing groups. The primary outcome of interest was the rate of any in-hospital stroke or death. Secondary outcomes include in-hospital stroke, death, and transient ischemic attacks. Stroke was defined as permanent neurologic symptoms that could include: full or partial visual loss, motor/sensory loss, speech abnormality, other new neurologic symptoms related to the right or left hemisphere, or symptoms that are bilateral motor, sensory, or visual loss, diplopia, or ataxia. Both ipsilateral and contralateral strokes were included in the post-procedural period. TIA was defined as any focal neurologic deficit that resolved within twenty-four hours. MI was defined as sustained troponin increase, based on EKG findings, or based on clinical findings.

Statistical Analysis

Categorical baseline characteristics were compared using Pearson $\chi 2$ test or Fisher exact test; continuous variables were compared using ANOVA. Multivariable logistic regression analysis was used to compare adjusted perioperative outcomes between TFCAS and CEA, and between TCAR and CEA within each timing cohort. Initial models included the following predictors: age, sex, race, ethnicity, presentation type (stroke versus TIA/AF), body mass index (BMI), hypertension, diabetes, coronary artery disease (CAD), congestive heart failure (CHF), prior coronary intervention, chronic obstructive pulmonary disease (COPD), hemodialysis, smoking status, degree of stenosis, contralateral occlusion, prior ipsilateral carotid intervention, use of general anesthesia and preoperative medications (aspirin, P2Y12 receptor antagonists, anticoagulants, beta blockers, angiotensin converting enzyme (ACE) inhibitors, and statins). Stepwise backward selection was then performed, and covariates were chosen based on Akaike's Information Criterion (AIC) as well as clinical judgement. The final adjusted model for urgent interventions included: presentation, age, sex, dialysis, diabetes, and pre-operative aspirin. The final adjusted model for early interventions included: presentation, age, race, CAD, hypertension, and ethnicity. The final adjusted model for late interventions included: presentation, age, prior coronary intervention, prior ipsilateral CEA or TFCAS, dialysis, ethnicity, pre-operative aspirin, and pre-operative beta-blockers. All analyses were clustered by centers to account for intragroup correlation and all appropriate theory-based categorical-categorical interactions were tested for and those that were found significant were presented. Hosmer-Lemeshow tests were used to assess the discrimination and calibration of the models.[16] Analysis was completed using R statistical software program (version 3.6.2). A p-value <0.05 was considered statistically significant.

Results

A total of 18,643 patients were included in this analysis; 2,006(10.8%) underwent urgent revascularization, 7,423(39.8%) underwent early revascularization, and 9,214(49.4%)

underwent late revascularization. Almost all demographic characteristics were significantly different between the three revascularization methods in each timing cohort. TCAR patients tended to be older and to have more significant comorbidities. CEA patients were more likely to present with stroke while TFCAS patients were less likely to undergo general anesthesia. (Table 1) We found comparable results regardless of whether we included or excluded patients with restenotic lesions. We elected to include this patient population for the purposes of maximizing the power of the study.

Urgent Revascularization (0–2 days after latest symptoms)

A total of 2,006 (10.8%) patients underwent urgent revascularization; the majority of which underwent CEA(n=1112, 55.4%) whereas 144(7.2%) underwent TCAR and 750(37.4%) TFCAS. On univariable analysis, the rates of in-hospital stroke (TCAR, 5.6% vs. TFCAS, 3.6% vs. CEA, 3.1%; p=0.28) were comparable between TCAR, TFCAS, and CEA. However, rates of in-hospital stroke/death (TCAR, 6.5% vs. TFCAS, 6.9% vs. CEA, 4.0%, p=0.02) were significantly different between revascularization methods, due to increased odds of death among urgent TFCAS (TCAR, 1.4% vs. TFCAS, 3.8% vs. CEA, 0.9%, p<0.001). Rates of in-hospital TIA were also significantly different (TCAR, 3.5% vs. TFCAS, 0.4% vs. CEA, 0.6% p=0.01). After adjusting for potential confounders, no significant difference was observed between TCAR and CEA in in-hospital stroke/death [OR:1.9, 95%CI:0.9–4.0, p=0.10]. On the other hand, urgent TFCAS was associated with increased odds of in-hospital stroke/death compared with urgent CEA [OR:1.7, 95%CI:1.0–2.9, p=0.03] driven by mortality [OR:4.3, 95%CI:2.0–9.4, p<0.001], with no difference in in-hospital stroke [OR:1.1, 95%CI:0.6–2.1, p=0.68]. (Table 2)

Early Revascularization (3–14 days after onset of symptoms)

Out of 7423 (39.8%) patients undergoing early carotid revascularization: 928(12.5%) had TCAR, 1369(18.4%) had TFCAS, and 5,126(69.1%) had CEA. The rates of in-hospital stroke/death trended towards significance (TCAR, 2.9%, TFCAS,3.8% vs. CEA, 2.5%, vs. p=0.05). In comparison, in-hospital TIA (TCAR, 1.1% vs. TFCAS, 1.4% vs. CEA, 0.6%, p=0.01), death (TCAR, 1.0% vs. TFCAS, 1.3% vs. CEA, 0.6%, p=0.03), stroke/TIA (TCAR, 3.6%, vs. TFCAS, 4.2%, vs. CEA, 2.7%, p=0.02), and stroke/death/MI (TCAR, 3.2% vs. TFCAS, 4.5%, vs. CEA, 3.0%, p=0.04) were all significantly different between the three groups. On adjusted analysis, TCAR and CEA had comparable odds of all complications. On the other hand, TFCAS was associated with significantly increased odds of in-hospital stroke/death [OR:1.6, 95%CI:1.1–2.4, p=0.01], due to increased odds of death [OR:2.4, 95%CI:1.3–4.6, p=0.01] when compared to CEA. However, no significant difference was observed in the odds of in-hospital stroke between early TFCAS and CEA [OR:1.4, 95%CI:0.9–2.1, p=0.15]. The adjusted odds of TIA, stroke/TIA and stroke/death/MI were also significantly higher after TFCAS. (Table 3)

Late Revascularization (15–180 days after onset of symptoms)

A total of 9,214 (49.42%) patients underwent late revascularization: 1,536(16.7%) had TCAR, 1,618(17.6%) TFCAS, and 6,060(65.8%) had CEA. The rates of in-hospital stroke/death were 1.6% after CEA vs. 2.3% after TCAR vs. 2.8% after TFCAS (p=0.003). The crude rates of other in-hospital outcomes are shown in Table 4. On adjusted analysis, no significant differences were observed in in-hospital adverse outcomes between late TCAR vs. CEA [stroke/death: OR:1.5, 95%CI:0.9–2.3, p=0.08]. However, compared to late CEA, late TFCAS was associated with 1.9 times the odds of in-hospital stroke/death [OR:1.9, 95%CI:1.2–3.0, p=0.009] and 1.6 times the odds of in-hospital stroke [OR:1.6, 95%CI:1.0–2.6, p=0.047]. (Table 4).

Discussion

This study compared perioperative outcomes among three carotid revascularization procedures performed at urgent, early and late time points after symptom onset. Compared to CEA, TFCAS had increased odds of perioperative complications at all time points with 4.3 times the odds of death when performed urgently, 2.4 times the odd of death when performed early and twice the odds of stroke/death when performed late. Conversely, TCAR and CEA did not have significant differences in odds of perioperative stroke but did have increased odds of stroke/TIA within the urgent cohort. These findings were mostly driven by increased odds of TIA as the adjusted odds ratio for in-hospital stroke bordered on significance [OR: 2.1, 95%CI: 1.0–4.5, p=0.067]. In addition, both urgent TCAR and urgent TFCAS had greater than the recommended threshold of 6% rate of perioperative stroke/death. These results suggest that urgent revascularization is safest with CEA but, in all other timing strata, TCAR and CEA have comparable outcomes. It is possible that findings are limited by a small population of patients undergoing TCAR, especially within the urgent group.

Ideally, carotid revascularization is performed as early as possible to prevent the risk of recurrent ipsilateral ischemic stroke. However, multiple studies have reported increased stroke risk within the early period after a patient’s first symptoms. One such study found this risk to be 2.7% in the first day, 5.3% in the first three days, and 11.5% within 14-days after symptom onset.[17] A population based study including over 600,000 patients in Oxfordshire found that this risk was higher, at 21% at two weeks and, among patients who received further delays in revascularization, up to 32% at 12 weeks, of which half were disabling or fatal strokes.[18] These cases all represent preventable morbidity and mortality had patients undergone early revascularization. In addition, early randomized clinical trials have found that long-term benefit from carotid revascularization may be limited to the first two weeks after symptoms[3] and current Society of Vascular Surgery guidelines recommend revascularization within this period.[9] However, we found that most symptomatic patients underwent revascularization after the recommended 14-day window. It is difficult to assess the reason for this delayed intervention in the context of a retrospective dataset and further prospective studies are needed to understand this paradigm. This finding highlights the utility of a large, international dataset like VQI and presents an opportunity to improve quality of care.

This balance between the risks of recurrent, perioperative, and long-term stroke differs for different revascularization procedures. Trends in these differences seem to persist despite the timing of revascularization. For example, it is well established that TFCAS has higher perioperative risks than CEA and studies found that these differences in perioperative stroke persist regardless of timing of procedure after symptom onset.[10,19] Similarly, a sub-analysis of the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST) did not find timing to predict periprocedural outcomes after TFCAS vs. CEA.[20] Another study combining the data from five RCT's found that TFCAS within one week of symptoms had between 6 to 8 times increased risk of perioperative complications compared to CEA [any stroke or death: adjusted relative risk (RR): 6.74 (2.07–21.92); fatal or disabling stroke: adjusted RR: 8.38 (1.09–64.76), p=0.04]. Among procedures delayed to at least one week after symptoms, TFCAS was also associated with increased risks but the adjusted RR was lower [any stroke or death: adjusted RR: 2.00 (1.50–2.68), p<0.0001; fatal or disabling stroke: adjusted RR: 1.77 (1.10–2.85), p=0.02].[11] Our study identified a 4-fold increase in the odds of in-hospital stroke/death after TFCAS in the urgent cohort that decreased to a 2-fold increase in odds in the early and late cohort. It is possible that the discrepancy between our study and the aforementioned studies are due to the structural differences in highly selective patients in randomized clinical trials versus a real-world observational large-database study.

A potential biologic explanation to our findings could be plaque instability and evolution over time in patients with symptomatic carotid artery stenosis. Several studies analyzing plaque morphology stratified by time to surgery have found a correlation between plaque inflammatory biomarkers, stability, and time to surgery.[21,22] Although these studies combined all plaques operated upon within 30-days, their results suggest that plaques evolve into more stable phenotypes with time which could influence perioperative risk. A study looking at plaque debris and inflammatory biomarkers after carotid artery stenting found that serum inflammatory markers, including pregnancy-associated plasma protein-A, high-sensitivity C-reactive protein, and IL-6, were significantly elevated after stenting.[23] It is possible that this persistent inflammatory milieu after stenting contributed to increased odds of death in the urgent cohort, resulting in potential survival bias in post-operative rates of stroke. Once systemic inflammation has decreased, differences in stroke risk may become less apparent.

Of note, our study did not directly compare the effect of timing on post-operative outcomes. It is generally accepted that earlier interventions are associated with increased risk,[24] although it is possible that a certain patient population subset may be eligible for emergent revascularization. While no model or consensus statement has been built to address this, important characteristics to consider include comorbidities and whether patients present with stroke or TIA.[24,25] The purpose of our study was to identify what method of revascularization is safest for these patients and for patients that undergo later revascularization. Some limitations to our study include those inherent to any retrospective analysis of large database, including coding errors, incomplete data, selection and other systematic biases. However, the Vascular Quality Initiative is both validated and widely published. Because this was a retrospective study, there may be unmeasured confounders that influenced what method of revascularization patients were provided. In addition, the most robust data provided within the VQI is during the post-procedural, in-hospital period, therefore we did not analyze data on 30-day outcomes. While this is a limitation to this dataset, previous studies have found that the majority of post-operative complications occur within the first three days after the index procedure.[26]

Conclusion

Our study demonstrated that urgent revascularization is associated with increased risk, regardless of the procedure. TFCAS is associated with increased odds of stroke and/or death at all time points while TCAR and CEA had comparable outcomes outside of the urgent period. In addition, more than half of symptomatic patients undergoing carotid revascularization are treated after the recommended two-week period. Further studies are needed to identify steps for quality improvement.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Sources of Funding

Christina Cui, BS was supported by an NIH grant 1TL1TR001443–01 at the time of the study. This work does not represent the views of the NIH.

Disclosures

MM is a site PI for ROADSTER I and ROADSTER II, and National PI for ROADSTER I long term follow-up study. MS has received consulting fees for Philips, Silk Road Medical, Medtronic, Endologix, Cook, and Abbott outside the scope of this work. CC was in part funded by the National Institutes of Health at the time of the study.

Non-standard Abbreviations and Acronyms:

Abbreviation	Explanation
CEA	Carotid endarterectomy
CREST	Carotid Revascularization Endarterectomy versus Stenting Trial
SVS	Society for Vascular Surgery
TCAR	Transcarotid artery revascularization
TFCAS	Transfemoral carotid artery stenting
VQI	Vascular Quality Initiative

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Table 1.

Demographics

	Urgent (n=2006, 10.76%)				Early (n=7423, 39.82%)				Late (n=9214, 49.42%)			
	TCAR (n=144)	TFCAS (n=750)	CEA (n=1112)	P-Value	TCAR (n=928)	TFCAS (n=1369)	CEA (n=5126)	P-Value	TCAR (n=1536)	TFCAS (n=1618)	CEA (n=6060)	P-Value
Demographics												
Sex (Female)	54 (37.5)	234 (31.2)	384 (34.5)	0.19	351 (37.8)	478 (34.9)	1905 (37.2)	0.25	544 (35.4)	577 (35.7)	2289 (37.8)	0.11
Age	72.6 ± 10.1	69.6 ± 10.5	69.2 ± 10.3	< 0.01	73.2 ± 10.4	69.8 ± 10.1	69.9 ± 10.6	< 0.001	72.8 ± 9.8	69.7 ± 9.9	70 ± 10.1	< 0.001
Race (Non-white)	12 (8.3)	109 (14.5)	147 (13.2)	0.13	128 (13.8)	177 (12.9)	702 (13.7)	0.74	142 (9.3)	190 (11.7)	611 (10.1)	0.06
Ethnicity (Hispanic)	4 (2.8)	28 (3.7)	33 (3)	0.62	35 (3.8)	50 (3.7)	217 (4.3)	0.55	62 (4.1)	55 (3.4)	226 (3.7)	0.63
BMI	29.9 ± 6	29.1 ± 6.2	29.1 ± 6.1	0.34	28.3 ± 6.0	28.8 ± 6.6	28.4 ± 5.9	0.03	28.7 ± 8.1	28.6 ± 6.3	28.5± 6.3	0.45
Comorbidities												
Diabetes	57 (39.6)	242 (32.3)	366 (33)	0.23	362 (39)	544 (39.8)	1754 (34.2)	< 0.001	612 (39.8)	671 (41.5)	2134 (35.2)	< 0.001
Hypertension	128 (88.9)	616 (82.1)	961 (86.5)	0.01	838 (90.3)	1211 (88.5)	4454 (86.9)	0.01	1397 (91)	1442 (89.1)	5317 (87.7)	0.001
Congestive Heart Failure	25 (17.4)	81 (10.8)	93 (8.4)	< 0.01	168 (18.1)	228 (16.7)	497 (9.7)	< 0.001	258 (16.8)	290 (17.9)	597 (9.8)	< 0.001
Coronary Artery Disease	56 (38.9)	232 (30.9)	205 (18.5)	< 0.001	388 (41.8)	537 (39.2)	1090 (21.3)	< 0.001	713 (46.4)	692 (42.8)	1332 (22.0)	< 0.001
History of CABG or PCI	44 (30.8)	202 (26.9)	254 (22.9)	0.04	302 (32.5)	446 (32.6)	1264 (24.7)	< 0.001	543 (35.4)	570 (35.2)	1615 (26.7)	< 0.001
Chronic Obstructive Pulmonary Disease	22 (15.3)	163(21.7)	211 (19.0)	0.13	222 (23.9)	353 (25.8)	1054 (20.6)	< 0.001	456 (29.7)	456 (28.2)	1405 (23.2)	< 0.001
Smoking (Any History)	79 (54.9)	490 (65.8)	652 (58.5)	< 0.01	530 (57.1)	840(61.5)	3081(60.2)	0.05	740 (48.3)	853 (52.8)	3174 (52.4)	0.001
GFR<60	82 (57.7)	393 (53.9)	515 (46.9)	< 0.01	508 (55.8)	673 (50.4)	2531 (50.1)	0.01	910 (60.5)	856 (54.4)	3128 (52.4)	< 0.001
Dialysis	2 (1.4)	8 (1.1)	10 (0.9)	0.83	15 (1.6)	26 (1.9)	44 (0.9)	< 0.01	26 (1.7)	20 (1.2)	44 (0.7)	0.001
Prior Ipsilateral Intervention	12 (8.3)	51 (6.8)	15 (1.4)	< 0.01	84 (9.1)	188 (13.7)	70 (1.4)	< 0.001	160 (10.4)	277 (17.1)	87 (1.4)	< 0.001
Prior Ipsilateral CEA	12 (8.3)	42 (5.6)	14 (1.3)	< 0.001	81 (8.7)	170 (12.4)	63 (1.2)	< 0.001	148 (9.6)	254 (15.7)	78 (1.3)	< 0.001
Prior Ipsilateral CAS	0 (0)	10 (1.3)	2 (0.2)	< 0.01	5 (0.5)	27 (2.0)	8 (0.2)	< 0.001	17 (1.1)	35 (2.2)	9 (0.1)	< 0.001
Preoperative Hemoglobin (g/dL)	13.0± 2.1	13.3 ± 2.0	13.2 ± 2.1	0.16	13.0± 2.1	13.0± 2.1	13.1 ± 2.7	0.02	13.1 ± 1.9	13.1 ± 1.9	13.3 ± 1.9	< 0.001
Preoperative Medications												
Aspirin	127 (88.2)	536 (71.5)	866 (77.9)	< 0.001	833 (89.9)	1208 (88.2)	4293 (83.8)	< 0.001	1417 (92.2)	1442 (89.1)	5122 (84.6)	< 0.001

	Urgent (n=2006, 10.76%)				Early (n=7423, 39.82%)				Late (n=9214, 49.42%)			
	TCAR (n=144)	TFCAS (n=750)	CEA (n=1112)	P-Value	TCAR (n=928)	TFCAS (n=1369)	CEA (n=5126)	P-Value	TCAR (n=1536)	TFCAS (n=1618)	CEA (n=6060)	P-Value
Beta Blockers	76 (52.8)	312 (41.7)	545 (49.1)	< 0.01	498 (53.7)	707 (51.7)	2477 (48.4)	< 0.01	856 (55.7)	827 (51.1)	2972 (49.1)	< 0.001
Statin	118 (81.9)	492 (65.8)	853 (76.7)	< 0.001	833 (89.8)	1153 (84.2)	4371 (85.3)	< 0.001	1402 (91.3)	1424 (88.1)	5266 (86.9)	< 0.001
P2Y12 Inhibitors	107 (74.3)	375 (50.1)	366 (32.9)	< 0.001	780 (84.1)	1062 (77.6)	2004 (39.1)	< 0.001	1386 (90.2)	1361 (84.1)	2738 (45.2)	< 0.001
ACE Inhibitors	68 (47.2)	330 (44.1)	531 (47.8)	0.28	445 (48.0)	635 (46.4)	2342 (45.7)	0.44	791 (51.5)	788 (48.7)	3126 (51.6)	0.11
Presentation												
Stroke	71 (49.3)	544 (72.5)	808 (72.7)	< 0.001	528 (56.9)	898 (65.6)	4139 (80.7)	< 0.001	779 (50.7)	844 (52.2)	4041 (66.7)	< 0.001
TIA or AF	73 (50.7)	206 (27.5)	304 (27.3)		400 (43.1)	471 (34.4)	987 (19.3)		757 (49.3)	774 (47.8)	2019 (33.3)	
Stenosis > 80%	63 (45.0)	358 (48.4)	513 (47.1)	0.71	391 (42.4)	664 (49.1)	2051 (40.3)	< 0.001	679 (44.6)	765 (48.0)	2341 (39.2)	< 0.001
General Anesthesia	117 (81.2)	155 (20.7)	1061 (95.5)	< 0.001	709 (76.5)	255 (18.7)	4848 (94.6)	< 0.001	1254 (81.6)	267 (16.5)	5655 (93.3)	< 0.001
ASA Class												
1	3 (2.1)	3 (0.4)	0 (0)		5 (0.5)	9 (0.7)	19 (0.4)		5 (0.3)	23 (1.5)	22 (0.4)	
2	3 (2.1)	68 (9.8)	31 (2.8)		15 (1.6)	173 (13.5)	146 (2.9)		54 (3.5)	242 (15.6)	212 (3.5)	
3	85 (59.0)	410 (59.1)	711 (64.1)	< 0.001	557 (60.3)	817 (63.9)	3500 (68.4)	< 0.001	1016 (66.3)	1020 (65.9)	4479 (74.0)	< 0.001
4	53 (36.8)	205 (29.5)	363 (32.7)		346 (37.4)	279 (21.8)	1453 (28.4)		458 (29.9)	263 (17.0)	1335 (22.1)	
5	0 (0)	8 (1.2)	4 (0.4)		1 (0.1)	0 (0)	2 (0)		0 (0)	0 (0)	1 (0.0)	

Table 2.

In-hospital Outcomes of Patients Undergoing Urgent Revascularization

	Unadjusted Analysis				Adjusted Analysis				
	CEA	TFCAS	TCAR	Chi-Square	CEA	TFCAS		TCAR	
	n (%)	n (%)	n (%)	P-Value	Adjusted OR (95% CI)	Adjusted OR (95% CI)	P-Value	Adjusted OR (95% CI)	P-Value
Stroke	35 (3.1)	27 (3.6)	8 (5.6)	0.283	Reference	1.1 (0.62, 2.08)	0.679	2.1 (1.0, 4.5)	0.067
TIA	7 (0.6)	3 (0.4)	5 (3.5)	0.005	Reference	0.6 (0.2, 2.3)	0.496	5.2 (1.3, 20.3)	0.019
Death	10 (0.9)	27 (3.8)	2 (1.4)	< 0.001	Reference	4.3(2, 9.4)	<0.001	1.5 (0.3, 7.2)	0.580
MI	16 (1.4)	6 (0.8)	1 (0.7)	0.482	Reference	0.6 (0.2, 1.4)	0.231	0.4 (0.1, 3.1)	0.392
Stroke/TIA	42 (3.8)	30 (4.0)	12 (8.3)	0.050	Reference	1.1 (0.6, 1.8)	0.860	2.6 (1.3, 5.2)	0.008
Stroke/ Death	44 (4.0)	49 (6.9)	9 (6.5)	0.018	Reference	1.7 (1, 2.9)	0.0338	1.9 (0.9, 4)	0.098
Stroke/ Death/MI	57(5.1)	53 (7.4)	9 (6.5)	0.130	Reference	1.5 (0.9, 2.3)	0.105	1.4 (0.7, 3.0)	0.399

Table 3:

In-hospital Outcomes of Patients Undergoing Early Revascularization

	Unadjusted Analysis				Adjusted Analysis				
	CEA	TFCAS	TCAR	Chi-Square	CEA	TFCAS		TCAR	
	n (%)	n (%)	n (%)	P-Value	Adjusted OR (95% CI)	Adjusted OR (95% CI)	P-Value	Adjusted OR (95% CI)	P-Value
Stroke	110 (2.1)	38 (2.8)	23 (2.5)	0.345	Reference	1.4 (0.9, 2.1)	0.150	1.2 (0.7, 1.8)	0.518
TIA	31 (0.6)	19 (1.4)	10 (1.1)	0.011	Reference	2.2 (1.2, 4.0)	0.010	1.3 (0.6, 3.3)	0.515
Death	30 (0.6)	16 (1.3)	9 (1.0)	0.029	Reference	2.4 (1.3, 4.6)	0.007	1.5 (0.7, 3.2)	0.278
MI	32 (0.6)	9 (0.7)	3 (0.3)	0.562	Reference	0.9 (0.4, 1.9)	0.777	0.4 (0.1, 1.4)	0.136
Stroke/TIA	140 (2.7)	57 (4.2)	33 (3.6)	0.018	Reference	1.6 (1.1, 2.3)	0.011	1.2 (0.8, 1.9)	0.413
Stroke/ Death	129 (2.5)	48 (3.8)	26 (2.9)	0.054	Reference	1.6 (1.1, 2.4)	0.014	1.1 (0.7, 1.7)	0.655
Stroke/ Death/MI	155(3.0)	57 (4.5)	29 (3.2)	0.040	Reference	1.6 (1.1, 2.3)	0.018	1.0(0.6, 1.5)	0.889

Table 4:

In-hospital Outcomes of Patients Undergoing Late Revascularization

	Unadjusted Analysis				Adjusted Analysis				
	CEA	**TFCAS**	**TCAR**	**Chi-Square**	**CEA**	**TFCAS**		**TCAR**	
	n (%)	**n (%)**	**n (%)**	**P-Value**	**Adjusted OR (95% CI)**	**Adjusted OR (95% CI)**	**P-Value**	**Adjusted OR (95% CI)**	**P-Value**
Stroke	85 (1.4)	36 (2.2)	30 (2)	0.039	Reference	1.6 (1.0, 2.6)	0.047	1.5 (0.9, 2.3)	0.120
TIA	27 (0.4)	14 (0.9)	12 (0.8)	0.062	Reference	2.0(1.0, 3.9)	0.042	1.5 (0.8, 3.1)	0.230
Death	19 (0.3)	11 (0.7)	7 (0.5)	0.079	Reference	1.9 (0.6, 5.8)	0.260	1.2 (0.5, 2.7)	0.662
MI	42 (0.7)	7 (0.4)	11 (0.7)	0.492	Reference	0.6 (0.3, 1.4)	0.232	0.9 (0.5, 1.7)	0.695
Stroke/TIA	111 (1.8)	49 (3)	42 (2.7)	0.004	Reference	1.7 (1.1, 2.6)	0.009	1.5 (1.0, 2.3)	0.052
Stroke/ Death	95 (1.6)	44 (2.8)	34 (2.3)	0.003	Reference	1.9 (1.2, 3)	0.009	1.5 (0.9, 2.3)	0.084
Stroke/ Death/MI	133(2.2)	50 (3.23)	42 (2.8)	0.042	Reference	1.5 (1.0, 2.3)	0.055	1.3 (0.9, 1.8)	0.253