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TransCarotid Revascularization with Dynamic Flow reversal versus Carotid Endarterectomy in the Vascular Quality Initiative Surveillance Project

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MINI-ABSTRACT

In this propensity score-matched analysis of the Vascular Quality Initiative Tanscarotid Artery Revascularization (TCAR) Surveillance Project, no differences were observed between TCAR with dynamic flow reversal and carotid endarterectomy (CEA) in the rates of perioperative of stroke or death. However, compared with CEA, TCAR was associated with a reduction in the risk of postoperative myocardial infarction, cranial nerve injury and a shorter length of stay (≤ 1 day).

STRUCTURED ABSTRACT

Objective: To compare the outcomes of TransCarotid Artery Revascularization with flow reversal (TCAR) to the gold standard carotid endarterectomy (CEA) using data from the Society for Vascular Surgery Vascular Quality Initiative TCAR Surveillance Project.

Summary Background Data: TCAR is a novel minimally invasive procedure for carotid revascularization in high-risk patients that is associated with significantly lower stroke rates compared with carotid artery stenting via the transfemoral approach.

Methods: Patients in the United States and Canada who underwent TCAR and CEA for carotid artery stenosis (2016- 2019) were included. Propensity scores were calculated based on baseline clinical variables and used to match patients in the two treatment groups (n=6,384 each). The primary endpoint was the combined outcome of perioperative stroke and/or death.

Results: No significant differences were observed between TCAR and CEA in terms of in-hospital stroke/death [TCAR,1·6% vs.CEA,1·6%,RR (95% CI):1·01(0·77-1·33),P=·945],stroke [1·4% vs.1·4%,RR(95%CI):1·02(0·76-1·37),P=·881], or death [0·4% vs.0·3%,RR (95%CI):1·14 (0·64-2·02),P=·662].Compared to CEA,TCAR was associated with lower rates of in-hospital myocardial infarction [0·5% vs. 0·9%,RR (95%CI):0·53 (0·35-0·83),P=·005], cranial nerve injury [0·4% vs.2·7%,RR(95%CI):0·14(0·08-0·23),P<·001], and post-procedural hypertension [13% vs.18·8%,RR(95% CI):0·69(0·63-0·76),P<·001].They were also less likely to stay in the hospital for more than one day [26·4% vs.30·1%,RR (95%CI):0·88(0·82-0·94), P<·001].No significant interaction was observed between procedure and symptomatic status in predicting postoperative outcomes.At one year, the incidence of ipsilateral stroke or death was similar between the two groups [HR (95%CI):1·09(0·87-1·36), P=·44].

Conclusions: This propensity-score matched analysis demonstrated significant reduction in the risk of postoperative myocardial infarction and cranial nerve injury after TCAR compared to CEA, with no differences in the rates of stroke/death.

INTRODUCTION:

Prior evidence has raised concerns regarding the transfemoral approach for performing carotid artery stenting (TFCAS) due to a higher risk of perioperative stroke and a significantly higher incidence of iatrogenic emboli shed after CAS compared to the gold standard carotid endarterectomy (CEA). [1-4] By directly accessing the common carotid artery, TransCarotid Revascularization with flow reversal (TCAR) circumvents aortic arch manipulation. Moreover, cerebral flow reversal provides protection prior to crossing the carotid lesion and throughout the procedure. [5-7] The neuroprotective effects from flow reversal have also led to a decrease in perioperative cerebral embolic rates on diffusion-weighted imaging, approaching rates observed with CEA.[8-10]

The TCAR Surveillance Project was established by the Society for Vascular Surgery (SVS) Vascular Quality Initiative (VQI) in collaboration with the Food and Drug Administration (FDA) and the Centers for Medicare & Medicaid Services (CMS) to compare the real-world outcomes of TCAR with CEA. Initial studies were promising; however, they were preliminary, underpowered, and used logistic regression instead of propensity-score matched analysis as requested by the FDA in consideration of expanding the indications and coverage for TCAR.[11-12] Comparison of 3,286 matched pairs of patients who underwent TCAR or TFCAS from September 2016 to April 2019 demonstrated 50% reduction in-hospital stroke or death after TCAR compared to TFCAS (1·6 vs. 3·1%, RR: 0·51, 95% CI: 0·37- 0·72, P<·001). [13] The present study uses the latest VQI-TCAR Surveillance Project data from consecutive 8,104 TCAR procedures between September 2016 and October 2019 and compares perioperative outcomes after TCAR versus CEA.

METHODS:

Dataset

The institutional review board approved this study, and waived the need for informed consent due to the de-identified nature of the data. The VQI is a CMS-approved prospectively maintained database containing patient- and procedure-specific data from different centers across all regions of the United States and Canada.[14] The SVS Patient Safety Organization launched the VQI TCAR Surveillance Project in 2016 to evaluate the safety and effectiveness of TCAR in high surgical risk, asymptomatic and symptomatic patients using FDA-cleared devices labeled for the transCarotid approach. CMS reimbursement for TCAR in asymptomatic patients is currently limited to centers participating in the TCAR Surveillance Project. Additional information on the VQI and TCAR Surveillance Project is available at www.vascularqualityinitiative.org.

Patients

All consecutive patients undergoing TCAR and CEA (without concomitant procedures) between September 2016 and October 2019 were identified in the SVS VQI TCAR Surveillance Project registry and the SVS VQI CEA database, respectively (CEA, 369 centers; TCAR, 296 centers). The final follow-up date was November 2019. Patients with tandem, traumatic or dissection lesions and those with more than one stented lesion were excluded. Carotid stents placed in conjunction with planned intracranial procedures and patients with unknown presenting symptom status were also excluded.

Variables Definition

Preoperative variables included patients' demographics (age, sex, race), and medical comorbidities such as hypertension (HTN), coronary artery disease (CAD), congestive heart failure (CHF), diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD) and dialysis. Prior cardiovascular procedures included a history of prior coronary artery bypass grafting (CABG) or percutaneous coronary intervention (PCI), prior CEA or CAS. Preoperative medication included platelet inhibitor therapy (aspirin, clopidogrel, prasugrel, ticlopidine, and ticagrelor), beta blockers, statins, anticoagulants, and ACE inhibitors if taken within 36 hours of the procedure. Other variables included type of anesthesia (general vs. local or regional), elective procedure (planned/scheduled procedure). Preoperative symptomatic status was defined as presence of ipsilateral cortical or ocular symptoms (amaurosis fugax, hemispheric transient ischemic attack (TIA) or stroke), up to 6 months before the intervention (see Table, Supplemental Digital Content 1, http://links.lww.com/SLA/C646, which shows VQI's definitions of the main variables used in this study)

Outcomes

The primary outcome was perioperative (in-hospital) stroke or death, (a composite endpoint of stroke or death). Secondary outcomes included the individual outcomes of in-hospital stroke, death, myocardial infarction, cranial nerve injury, 30-day stroke or death, as well as ipsilateral stroke or death at 1-year.Other outcomes included post-procedural hypotension or hypertension, access site bleeding requiring intervention, operative time, post-operative length of hospital stay

for more than one day, and discharge disposition. Stroke was defined as either ipsilateral or contralateral, cortical or vertebrobasilar, ischemic or hemorrhagic strokes. This was determined clinically by perioperative neurological symptoms with or without imaging confirmation. Myocardial infarction (MI) included both clinical MI and troponin-positive only MI. Clinical MI was defined as the presence of clinical symptoms (chest pain or shortness of breath) or electrocardiographic changes plus a rise of cardiac biomarkers (preferably troponin). Troponin rise alone was reported if there was a rise in cardiac biomarker values (preferably cardiac troponin) with at least one value above the 99th percentile upper reference limit and in the absence of the six qualifying criteria for MI or sudden death as defined by the VQI. However, troponin levels are not routinely measured in most asymptomatic VQI patients, which should be taken into consideration in interpreting the results. Cranial nerve injury included cranial nerve deficits that occurred after the procedure and persisted until time of discharge. Postoperative hypertension or hypotension is recorded if the patient requires more than one dose or continuous infusion of intravenous blood pressure medication for 15 minutes or longer. Procedure time was measured from the start of skin incision to the time of closure. Access site bleeding was defined as bleeding resulting in reoperation or needing any interventional treatment. Patients were considered to be discharged "home" as long as they returned to where they came from before the operation, even if their home was a nursing home or rehabilitation facility. Additionally, 1-year mortality is determined through linkage to the Social Security Death Index.

Statistical analysis

Comparisons of pre-operative variables between patients undergoing TCAR and patients undergoing CEA were performed using χ^2 and Fisher exact tests for categorical variables, and Student *t*-test or rank-sum test for continuous variables as appropriate. The mean standardized differences between the two groups were calculated for both continuous and categorical variables. An absolute standardized difference of ·10 or more was used to indicate imbalance between the groups. To create matched cohorts of patients, a propensity score (logit model) was calculated for each individual based on baseline clinical variables [age, gender, race, presenting symptoms, HTN, diabetes, CAD, CHF, prior CABG/PCI, COPD, CKD, dialysis, preoperative smoking status, prior CEA/CAS, ipsilateral stenosis more than 80%, prior contralateral CEA/CAS, preoperative medications (aspirin, P2Y12 antagonists, statins, anticoagulants, ACE inhibitors), presence of contralateral occlusion, elective procedures, and anesthesia technique] (see Table, Supplemental Digital Content 2, http://links.lww.com/SLA/C647, which compares baseline patients' characteristics between TCAR and CEA before and after Propensity Score Matching). All variables had less than 5% missing data. Observations were clustered in each center to reduce bias from hospital-level unmeasurable factors and to account for intragroup correlation. Treatment groups were matched on these propensity scores, using one-to-one matched analysis without replacement and with a caliper size of 0·1 (PSMATCH2 Stata module). Intergroup differences between the treatment groups and differences in perioperative outcomes were tested with the McNemar's test for categorical variables, and paired t-test, or Wilcoxon matched-pairs signed-rank test for continuous variables where appropriate. Relative

risk with 95% confidence intervals were estimated as the ratio of the probability of the outcome event in the patients treated with TCAR compared to patients treated with CEA. Ipsilateral stroke death rates in the matched cohorts were estimated at 1-year using Kaplan-Meier analysis, censoring patients lost to follow-up, and comparisons were made using bivariable Cox proportional hazard models.

The interaction between presenting symptomatic status and procedure type in predicting outcomes was evaluated by forcing these interaction terms into the regression models. Comparison of baseline patient characteristics in symptomatic and asymptomatic patients can be found in Supplementary Digital Contents two and three, respectively. All tests were two sided, and $P < \cdot 05$ was considered statistically significant. Analyses were performed using Stata/SE version 16.0 statistical software (StataCorp LP, College Station, Texas).

RESULTS

Baseline Characteristics

There were 53,869 patients who underwent CEA and 8,104 patients who underwent TCAR during the study period (See Figure, Supplemental Digital Content 5, http://links.lww.com/SLA/C652, which shows the change in the number of CEA and TCAR procedures in the Vascular Quality Initiative between September 2016 and October 2019. Compared to patients undergoing CEA, those undergoing TCAR were older [median age in years (IQR): 74 (67-80) vs. 71 (65-77)], less likely to be symptomatic (23·8% vs. 29·8%) although this was primarily related to a lower rate of amaurosis fugax in the TCAR group (12·8% vs· 17·4%). Both hemispheric TIA and stroke were more common in patients undergoing TCAR (TIA: 29·0% vs. 26·9%; stroke: 58·8% vs. 55·7%). Patients in the TCAR group also had more medical comorbidities such as CAD (51·9% vs. 26·6%), prior CABG/PCI (40·6% vs. 34·4%), CHF (18·0% vs. 11·3%), COPD (27·4% vs. 23·2%), CKD (39·1% vs. 33·5%) and dialysis (1·7% vs. 1·0%) (mean standardized differences were all >·10). They were also more likely to have prior history of carotid revascularization, and ipsilateral stenosis of ≥ 80%. The higher comorbidity profile in patients undergoing TCAR was also reflected in a higher use of pre-operative medications. After matching, 6,384 pairs of patients who underwent TCAR or CEA were identified, and the two cohorts were well matched (mean standardized differences were all <·10). Baseline characteristics and coexisting conditions before and after propensity-score matching are shown in Supplemental Digital Content 2, http://links.lww.com/SLA/C647.

Among these matched pairs, data on in-hospital stroke or death were available for all patients, and data on ipsilateral stroke or death at 1 year were available for 30.7% of patients undergoing TCAR and 48% of patients undergoing CEA.

Outcomes

The rates of in-hospital stroke or death were 1·6% in each group [RR (95% CI):1·01(0·77-1·33), P=·945]. In-hospital stroke [TCAR: 1·4%, CEA:1·4%, RR (95% CI): 1·02 (0·76-1·37), P=·881], and death [TCAR: 0·4%, CEA: 0·3%, RR (95% CI): 1·14 (0·64-2·02), P=·662] were not statistically different between the two cohorts (Table 1).

TCAR was associated with significantly lower rates of in-hospital MI [0·5% vs. 0·9%, RR (95%CI): 0·53 (0·35-0·83), P=·005], cranial nerve injury [0·4% vs. 2·7%, RR (95%CI): 0·14 (0·08-0·23), P<·001] and post-procedural hypertension [13·6% vs.19·6%, RR(95%CI): 0·70 (0·64-0·76), P<·001]. Clinical MI, defined as the presence of clinical symptoms or electrocardiographic changes plus a rise of cardiac biomarkers, was observed in 0.3% (n=19) of TCAR patients vs. 0.5% (n=32) of CEA patients (P=0.07). On the other hand, troponin-positive only MI was observed in 0.2% vs. 0.4% of TCAR and CEA patients, respectively (P=0.02). Patients undergoing TCAR had lower mean operative times compared to patients undergoing CEA (72.5 ± 29.3 minutes vs. 121.4 ± 47.7 minutes, P<0.001).

Protamine was given for 80.5% of patients undergoing TCAR compared to 73.9% of patients undergoing CEA (P<0.001). No interaction was observed between the type of the procedure (TCAR vs. CEA) and the use of protamine for heparin reversal in predicting the risk of in-hospital stroke/death (P of the interaction=0.11) or in-hospital MI (P of the interaction=0.46). On the other hand, there was a significant interaction between protamine use and procedure type in predicting the risk of bleeding requiring intervention (P of the interaction=0.02); when protamine was used, TCAR was associated with a significant decrease in the risk of bleeding compared to CEA (RR: 0.61, 95%CI:0.41-0.91, P=0.02). When no protamine was used, the risk of bleeding was similar between the two groups (RR:1.39, 95%CI:0.92-2.11, P=0.12).

Patients in the TCAR group were less likely to stay in the hospital for more than one day compared to patients undergoing CEA [29·8% vs. 34·1%, RR (95%CI): 0·88 (0·82-0·93), P<·001]. Non-home discharge (discharge to rehabilitation units, nursing homes, other hospitals) was not different between the two cohorts. At 30 days, no significant differences were observed between TCAR and CEA in terms of stroke or death [1·9% vs. 2·3%, RR (95% CI): 0·85 (0·67-1·08), P=·173], stroke [1·5% vs. 1·7%, RR (95% CI): 0·87 (0·66-1·15), P=·321], or death [0·7% vs. 0·8%, RR (95% CI):0·92 (0·61-1·38), P=·676]. At 1 year, no significant difference was observed in the risk of ipsilateral stroke or death between the two procedures [5·7% vs. 6.6%, HR (95%CI): 1·09 (0·87-1·36), P=·44] (Figure 1).

Symptomatic and Asymptomatic carotid artery stenosis

No significant interaction was identified between treatment and symptomatic status in predicting in-hospital stroke or death (P value for interaction = .309), stroke (P value for interaction =.591), or death (P value for interaction =.997) and in-hospital MI (P value for interaction=.746)

In symptomatic patients, no significant differences in baseline characteristics were found between the TCAR and CEA group, except for a higher percentage of patients with prior CABG/PCI in the TCAR group (33·8% vs. 28·8%) and higher general anesthesia use in the CEA group (86·5% vs. 83·0%) (see Table, Supplemental Digital Content 3, http://links.lww.com/SLA/C650, which shows the baseline characteristics of symptomatic patients undergoing TCAR and CEA, respectively). We further adjusted for the latter variables when comparing the outcomes between the two groups. In-hospital stroke or death was 2·2% in the TCAR group versus 2·6% in the CEA group [RR (95% CI): 1·13 (0·80-1·59), P=·490]. There were no statistically significant differences in stroke [2·1% vs. 2·2%, RR (95% CI): 0·93

(0·59-1·47), P=·754], or death [0·54% vs. 0·48%, RR (95% CI): 1·14 (0·44-2·94), P=·792] (Table 2).In patients with symptomatic carotid artery disease, there was a trend towards decreased risk of MI after TCAR compared with CEA, however, the differences were not statistically significant [0·5% vs. 1%, RR (95% CI): 0·47 (0·20-1·10), P=·075]. Compared to CEA, TCAR was associated with 88% reduction in cranial nerve injury [0·4% vs. 3·1%, RR (95% CI): 0·12 (0·05-0·29), P<·001], and 29% reduction in post-procedural hypertension [15·5% vs. 21·9%, RR (95% CI): 0·71 (0·61-0·82), P<·001]. Patients undergoing TCAR were less likely to have a hospital length of stay for more than one day [39·5% vs. 45·1%, RR (95% CI): 0·87 (0·81-0·95), P=·001] compared to patients in the CEA cohort.
In asymptomatic patients, there were no differences in baseline characteristics between TCAR and CEA (see Table, Supplemental Digital Content 4, http://links.lww.com/SLA/C651, which shows the comparison baseline characteristics of asymptomatic patients in the TCAR and CEA cohorts, respectively). The lack of a statistical difference in in-hospital stroke or death between the two cohorts was also observed in asymptomatic patients [1·4% vs. 1·3%, RR (95%CI): 1·13 (0·80-1·59), P=·490]. TCAR was associated with a significant reduction in MI [0·5% vs. 0·9%, RR (95%CI): 0·56 (0·34-0·93), P=·025], cranial nerve injury [0·4% vs. 2·6, RR (95% CI): 0·14 (0·08-0·25), P<·001] and post-procedural hypertension [13% vs. 18·8%, RR (95% CI): 0·69 (0·63-0·76), P<·001] compared with CEA.

DISCUSSION

Despite significant refinement in techniques and improvement in outcomes, the transfemoral approach for performing CAS continues to have almost twice the risk of perioperative stroke and death compared to CEA in real-world clinical settings. [15-19] The introduction of TCAR has provided another minimally invasive option for carotid revascularization in patients at high-risk for CEA.[11-13] The present analysis of 6,384 matched pairs of patients from an FDA approved project showed no significant differences in perioperative stroke or death after TCAR compared with CEA.
While initial published results of TCAR reflect only those of highly selected providers and centers within clinical trials, the TCAR Surveillance Project allows real-world evaluation of all patients treated with TCAR. An interim analysis of the first 1,182 TCAR cases in the TCAR Surveillance Project showed similar odds of stroke/death [OR (95%CI):1·3 (0·8-2·2)] and stroke/death/MI [OR (95%CI):1·4 (0·9-2·1)] compared to CEA patients. [11] This was also shown in a retrospective analysis of 292 patients who underwent TCAR at four institutions between 2013 and 2017 with no significant differences after propensity-score matching between TCAR and CEA in the rates of perioperative stroke/death/MI (2·1% vs 1·7%, P= NS). [20] In both studies TCAR was associated with a decreased rate of cranial nerve injury. The neuroprotective benefits after TCAR have also been demonstrated by similar cerebral embolic rates on diffusion-weighted imaging (DW-MRI) to those found during CEA.[10] In one study, ipsilateral new white lesions occurred in 10 (17·9%) of 56 patients on DW-MRI. [9] This is significantly lower than reported for TFCAS (50%) and similar to the rates of new DWI lesions in prior reports of CEA (17%).[21] The lack of concurrent comparison groups with similar timing of the MRI scans in the latter study make it difficult to draw firm conclusions. Nonetheless, these results further propose the potential benefits of direct cervical carotid access combined with

dynamic flow reversal during angioplasty and stenting in decreasing the number of emboli compared to distal filters.

In the present study, patients undergoing TCAR also had lower rates of perioperative MI compared with patients undergoing CEA. These favorable outcomes might be attributable to the minimally invasive nature of TCAR which eliminates the need for complete surgical dissection of the carotid artery bifurcation compared to CEA. Moreover, TCAR had a shorter operative time compared to CEA (mean operative time: 72.5 ± 29.3 minutes vs. 121.4 ± 47.7 minutes, P<0.001), which could suggest shorter anesthesia time and less hemodynamic changes and physiological stress on the patient. Another hypothesis is that the improved medical management and better supervision of high-risk patients undergoing TCAR might reduce their perioperative cardiac morbidity. It's also important to note that troponin levels are not routinely measured in most asymptomatic VQI patients, which might underestimate the rate of troponin-only MI. In the TCAR group, 12 patients (0.2%) had troponin-only MI, whereas 19 patients (0.3%) had clinical MI.

Patients in the TCAR treatment group also had lower rates of cranial nerve injury compared with CEA. Although permanent neurological deficits are rare, unresolved cranial nerve injuries may result in significant long-term disability and should be communicated to patients before they undergo surgery.[22-23] Cranial nerve injury is the most common neurologic complication of CEA ranging from 5·1% to 8·6% in clinical trials.[23-25] In CREST, these injuries occurred in 4·6% of patients undergoing CEA with 34% resolution at 30 days and 80·8% by 1 year.[23] In our cohort, TCAR was associated with significantly lower rates of cranial nerve injury present on discharge compared to CEA [0·4% vs. 2·7%, RR (95% CI): 0·14 (0·08-0·23), P<·001].

CEA practice patterns, including the use of shunts and cerebral monitoring techniques, are typically surgeon-dependent and differ greatly on a national level.[26] In the matched cohort, 52.3% of CEA cases had intraoperative shunting. Since intraoperative shunting might be associated with higher stroke/death, [26] we performed a subgroup analysis comparing in-hospital stroke/death between TCAR and CEA with and without intraoperative shunting. No significant difference was observed between TCAR and CEA without shunting (1.6% vs. 1.2%, aOR: 1.34, 95%CI:0.92-1.95, P=0.12), or between TCAR and CEA with intraoperative shunting (1.6% vs. 2.0%, aOR:0.83, 95%CI:0.59-1.17, P=0.28). On the other hand, in the VQI database, data on neuromonitoring techniques are only available for the CEA group. Of patients undergoing CEA under general anesthesia (n=5,418, 84.9%), 28.6% had EEG monitoring, 10.9 had % stump pressure measurements. The rest (15%) were performed under local/regional anesthesia. Neuro-monitoring techniques were not associated with an increased in the odds of stroke/death.

This study presents an updated and powerful analysis with a large cohort of patients who were matched on over 24 baseline variables. Nonetheless, it must be interpreted in light of certain limitations. First, the nature of the study precludes casual inferences. Second, there is a potential for selection bias introduced by the non-random allocation of interventions. Unmeasured confounders such as provider or patient preference, physician technical skills, and center-level policies might influence the procedure choice. Third, neurological outcomes are determined clinically without a formal neurological evaluation which might inflict some ascertainment bias. However, this would equally affect the treatment groups, and should not change our findings. All large, complex registries, whether clinical or administrative, are subject to some degree of error. The lack of

adjudicated stroke outcomes and the reliance on surgeons and centers' self-reported rates of stroke could lead to under-reporting of stroke rates, although this does bias both CEA and TCAR. However, in VQI, trained individuals from participating centers extract data from consecutive cases and complete prespecified case report forms. Multiple mechanisms are in place to assure the accuracy of data reported in SVS VQI. Data in the registry is constantly audited by and compared against billing data and inconsistencies are reconciled. Moreover, random audits of cases and specific variables are now being conducted by external auditors who gain access to the center's electronic medical records (EMR) data to verify accuracy of data entry.[27] Fourth, given the relatively smaller number of patients with symptomatic carotid artery stenosis, there is a possibility of type II error in reporting the risk of adverse events in these patients. Moreover, one-year follow up is not complete for all patients. Nonetheless, the primary endpoint was perioperative stroke or death since the advantage of TCAR would be more prominent in the immediate postoperative period. Several prior studies have demonstrated similar long-term outcomes between TFCAS and CEA, except for the perioperative period with higher rates of adverse events after TFCAS compared to CEA.[3-4,15-19]

CONCLUSION:

Analysis of patients undergoing TCAR in the VQI TCAR Surveillance Project showed no significant differences in perioperative stroke or death compared with CEA. TCAR was associated with lower rates of MI, cranial nerve injury and shorter length of stay (≤ 1 day). These promising outcomes will likely increase the role of TCAR in the management of carotid artery stenosis. Larger studies with longer follow-up, especially in symptomatic patients, are needed to further explore the benefits of TCAR in the treatment of carotid artery stenosis and stroke prevention.

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MM and HDA had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

The Society for Vascular Surgery Patient Safety Organization was not involved in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

MM and HDA were responsible for the design, and conduct of the study; the collection, management, analysis, and interpretation of the data; the preparation, review, and approval of the manuscript; and the decision to submit the manuscript for publication.

VK, JEJ, GJW, RLM, JC and MLS were responsible for the design and conduct of the study, the interpretation of the data, the review of the manuscript, and the decision to submit the manuscript for publication.

DECLARATION OF INTERESTS

MM is a site PI for ROADSTERI and ROADSTERII, and National PI for ROADSTERI long term follow-up study.

MLS is a consultant for Silk Road Medical, Medtronic, Endologix, Cook, and Abbott

VK is a National Co-PI for ROADSTERII.

RLM is a consultant and proctor for Silk Road Medical.
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FIGURE LEGENDS

Figure 1. Kaplan Meier Curve for Ipsilateral Stroke or Death after TransCarotid Artery Revascularization and Carotid Endarterectomy

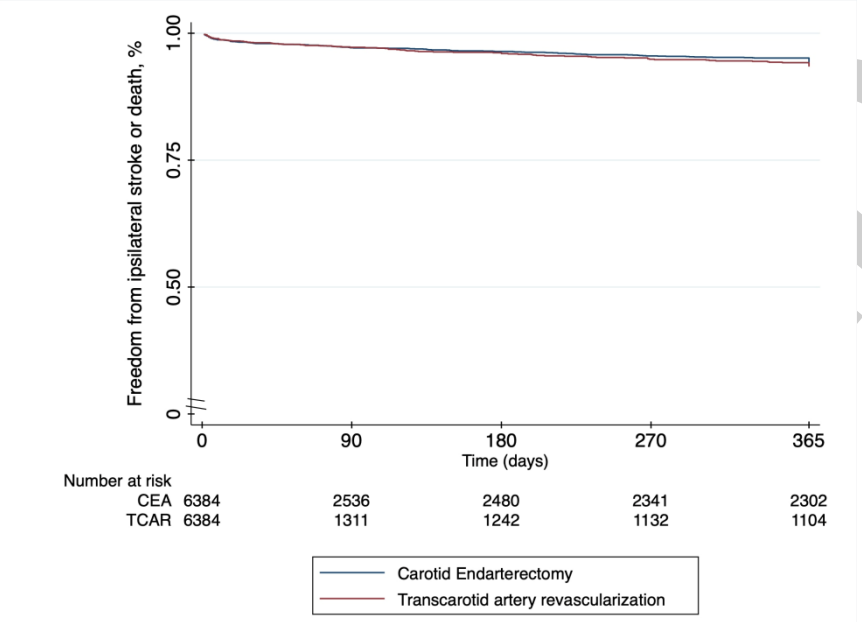

Table 1. In-Hospital Outcomes after Propensity Score Matching

	CEA (N=6,384)	TCAR (N=6,384)	TCAR vs· CEA	
In-hospital Outcomes	*N (%)*	*N (%)*	*Relative Risk (95 %CI)*	*P-value*
Stroke/Death	103 (1·6)	104 (1·6)	1·01 (0·77-1·33)	·945
Death	22 (0·3)	25 (0·4)	1·14 (0·64-2·02)	·662
Ipsilateral Stroke	66 (1·0)	80 (1·2)	1·21 (0·87-1·68)	·247
Stroke	89 (1·4)	91 (1·4)	1·02 (0·76-1·37)	·881
Myocardial infarction	58 (0·9)	31 (0·5)	0·53 (0·35-0·83)	·005
Stroke/Death/Myocardial infarction	153 (2·4)	130 (2·0)	0·85 (0·67-1·07)	·172
Cranial Nerve Injury	73 (2·7)	18 (0·4)	0·14 (0·08-0·23)	<·001
Post-procedural Hypotension	685 (10·7)	1,059 (16·6)	1·55 (1·41-1·71)	<·001
Post-procedural Hypertension	1,252 (19·6)	868 (13·6)	0·70 (0·64-0·76)	<·001
Bleeding with intervention	105 (1·6)	84 (1·3)	0·80 (0·60-1·06)	·127
LOS more than 1 day	2,174 (34·1)	1,905 (29·8)	0·88 (0·82-0·93)	<·001
Non-Home Discharge	450 (7·1)	444 (7·0)	0·99 (0·87-1·13)	·893

Abbreviations: CEA, carotid endarterectomy; TCAR, transCarotid artery revascularization; CI, confidence interval; LOS, length of stay

Table 2. In-Hospital Outcomes in Symptomatic and Asymptomatic Patients in the Matched Cohort

	Symptomatic (N=3,333)				Asymptomatic (N=9,435)			
	CEA (N=1,675)	TCAR (N=1,658)	TCAR vs· CEA*		CEA (N=4,709)	TCAR (N=4,726)	TCAR vs· CEA	
In-hospital Outcomes	*N (%)*	*N (%)*	*Relative Risk. (95 %CI)*	*P-value*	*N (%)*	*N (%)*	*Relative Risk (95 %CI)*	*P-value*
Stroke/Death	43 (2·6)	36 (2·2)	0·85 (0·55-1·31)	·458	60 (1·3)	68 (1·4)	1·13 (0·80-1·59)	·490
Death	8 (0·48)	9 (0·54)	1·14 (0·44-2·94)	·792	14 (0·3)	16 (0·3)	1·14 (0·56-2·33)	·722
Ipsilateral Stroke	33 (2·0)	31 (1·9)	0·95 (0·58-1·54)	·835	33 (0·7)	49 (1·0)	1·48 (0·95-2·30)	·080
Stroke	37 (2·2)	34 (2·1)	0·93 (0·59-1·47)	·754	52 (1·1)	57 (1·2)	1·09 (0·75-1·59)	·641
Myocardial infarction	17 (1·0)	8 (0·5)	0·47 (0·20-1·10)	·075	41 (0·9)	23 (0·5)	0·56 (0·34-0·93)	·025
Stroke/Death/Myocardial infarction	57 (3·4)	43 (2·6)	0·76 (0·51-1·12)	·172	96 (2·0)	87 (1·8)	0·90 (0·68-1·20)	·486
Cranial Nerve Injury	52 (3·1)	5 (0·4)	0·12 (0·05-0·29)	<·001	121 (2·6)	13 (0·4)	0·14 (0·08-0·25)	<·001
Post-procedural Hypotension	203 (12·1)	250 (15·2)	1·25 (1·05-1·49)	·010	482 (10·2)	809 (17·2)	1·67 (1·51-1·86)	<·001
Post-procedural Hypertension	366 (21·9)	255 (15·5)	0·71 (0·61-0·82)	<·001	886 (18·8)	613 (13·0)	0·69 (0·63-0·76)	<·001
Bleeding with intervention	35 (2·1)	21 (1·3)	0·61 (0·35-1·04)	·068	70 (1·5)	63 (1·3)	0·90 (0·64-1·26)	·527
LOS more than 1 day	756 (45·1)	655 (39·5)	0·87 (0·81-0·95)	·001	1,418 (30·1)	1,250 (26·4)	0·88 (0·82-0·94)	<·001
Non-Home Discharge	237 (14·2)	249 (15·1)	1·06 (0·90-1·25)	·464	213 (4·5)	195 (4·1)	0·91 (0·75-1·10)	·343

Abbreviations: CEA, carotid endarterectomy; TCAR, transCarotid artery revascularization; CI, confidence interval; LOS, length of stay

*Outcomes were further adjusted for prior CABG/PCI and anesthesia technique