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Impact of Conversion from Local/Regional to General Anesthesia on Outcomes in Transcarotid Artery Revascularization

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Background: This study evaluates impact of converting from local to general anesthesia on transcarotid artery revascularization (TCAR) outcomes and identifies risk factors predictive of conversions.

Methods: A total of 58,960 TCAR cases from the Vascular Quality Initiative (2018–2024) were categorized by anesthesia type: 6,831 local/regional anesthesia (LRA), 51,851 general anesthesia (GA), and 278 conversions from LRA to GA. In-hospital outcomes were compared using multivariate logistic regression, with stroke/death as the primary endpoint. Preoperative predictors of conversion were also assessed.

Results: Converted patients were oldest, more often obese, and more likely to undergo urgent procedures. Compared to LRA, conversion was associated with increased odds of in-hospital stroke/death (adjusted odds ratio [aOR] = 3.01; 95% confidence interval [CI], 1.54–5.36; $P < 0.001$), stroke/death/MI (aOR = 2.92; 95% CI, 1.58–5.00; $P < 0.001$), and prolonged hospital stay (aOR = 1.38; 95% CI, 1.05–1.80; $P = 0.020$). Compared to GA, converted patients had higher odds of stroke/death (aOR = 2.95; 95% CI, 1.55–5.09; $P < 0.001$) and stroke/death/MI (aOR = 2.75; 95% CI, 1.52–4.57; $P < 0.001$). Compared to LRA, GA was only associated with longer hospital stay. Age and urgent procedures were significant preoperative predictors of conversion to GA ($P < 0.05$).

Conclusion: Conversion from LRA to GA during TCAR is associated with higher rates of stroke, death, and MI compared to LRA or initial GA. Age and urgent TCAR procedures were identified as critical preoperative factors influencing conversion risk. These findings underscore the importance of meticulous preoperative risk assessment and optimal anesthesia selection to minimize conversions and enhance safety in TCAR.

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INTRODUCTION

Within the United States, 1 in 6 deaths from cardiovascular disease are due to stroke, costing up to \$56 billion dollars annually.¹ About 87% of all strokes are ischemic, with 10–20% being attributable to carotid artery stenosis.^{1,2} Providing appropriate treatment modalities for atherosclerotic carotid artery disease remains a crucial factor in reducing rates of stroke.³ While carotid endarterectomy (CEA) remains the gold standard revascularization procedure, transcatheter artery revascularization (TCAR), introduced in 2015, provides a minimally invasive treatment option with fewer adverse events compared to transfemoral carotid stenting (TFCAS) for high-risk patient populations.^{4–7} TCAR use within the United States has steadily increased since its introduction, accounting for 0.8% of carotid revascularization procedures in 2015 up to almost 22% in 2019 and in high risk patients, TCAR now accounts for the majority of procedures.⁸

TCAR may be performed under either local/regional anesthesia (LRA) or general anesthesia (GA).⁹ Prior studies on anesthetic management of TCAR show that while LRA is generally safe, physicians largely use GA.^{10,11} There are limited data on how anesthesia type affects TCAR outcomes, with most of our understanding of potential difference in outcomes derived from studies focused on CEA or TFCAS.^{12–14} Although infrequent, physicians may convert from LRA to GA intraoperatively if necessary or for patient comfort.¹⁵ There is currently a critical lack of information on the potential consequences of converting from regional to general anesthesia during TCAR.

Given that there may be a clinically relevant impact of anesthesia type conversion during these procedures, our goal is to evaluate the potential impacts of intraoperative conversion from LRA to GA on postoperative outcomes following TCAR, as well as to identify predictive risk factors for these conversions.

METHODS

Data Source

This is a retrospective cohort study using the Society for Vascular Surgery Vascular Quality Initiative (SVS-VQI) registry database (www.vqi.org). The VQI Carotid Artery Stenting (CAS) database includes information from over 1,000 medical centers in the United States and Canada and provides deidentified data on major vascular procedures, such as patient demographics, medical history, and

treatment outcomes. The STROBE guidelines (<https://www.strobe-statement.org/>) were used to ensure proper reporting of methods, results, and discussion. Because only deidentified data were used, the study was exempt from requiring individual patient consent or institutional board review, but it was approved by the SVS data safety organization (Protocol Number: 5597).

Patient Cohort

This study included all VQI patients undergoing TCAR for asymptomatic and symptomatic carotid stenosis from 2018 to 2024. We excluded records with missing information regarding anesthesia status. Patients under 18 years were also excluded from the analysis. Patients with nonatherosclerotic lesions (i.e., trauma, dissection, and fibromuscular dysplasia), more than one treated lesion, and planned intracerebral intervention were also excluded. The TCAR approach was then identified as utilizing a flow reversal protection device with transcatheter approach. Cohorts were then made by sorting by anesthesia status: LRA versus GA versus conversion from LRA to GA.

Variable Definitions and Outcomes

As defined by the VQI, local anesthesia encompasses intravenous sedation. Conscious sedation is categorized under local anesthesia due to its typical coadministration with local anesthesia. Regional anesthesia is specifically defined as cervical block anesthesia. Lastly, GA refers to sedation that necessitates a mask airway, laryngeal mask airway, or intubation. Coronary artery disease (CAD) was defined as a history of angina or myocardial infarction (MI). The estimated glomerular filtration rate was calculated using the new Chronic Kidney Disease Epidemiology Creatinine Equation (2021).¹⁶ Obesity was defined as body mass index (BMI) > 30 kg/m². Symptomatic status was defined as the presence of ipsilateral ocular or cortical transient ischemic attack, or stroke within 6 months prior to the index procedure in accordance with SVS reporting standards.¹⁷ Prolonged length of stay was defined as ≥ 2 days.

The primary outcome was in-hospital stroke/death. Stroke was defined as having symptoms lasting >24 hours involving neurological or visual deficits. Secondary outcomes included in-hospital stroke, death, and MI as well as prolonged length of stay (≥ 2 days). MI was indicated by troponin level, electrocardiogram, or diagnosed clinically according to American College of Cardiology criteria.¹⁸

Statistical Analysis

We compared demographics, comorbidities, and procedural characteristics between each cohort analysis. We used 2-way ANOVA test to compare continuous baseline demographic characteristics and the Pearson χ^2 test or Fisher's exact test to compare categorical baseline characteristics. Postoperative outcomes were evaluated using univariable and multivariable logistic regression analysis. Multivariate analysis was conducted to account for the following potential secondary confounders based on prior literature: age, sex, race, ethnicity, insurance, BMI, symptomatic status, diabetes, hypertension, congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD), prior occlusions, coronary artery bypass graft/percutaneous coronary intervention (CABG/PCI), procedure urgency, smoking, and use of preoperative medications. In our analysis, we checked for model calibration and accuracy using the Hosmer-Lemeshow goodness of fit test. The discrimination ability of the model was evaluated using the area under the receiver operating characteristic curve.

A multivariable logistic regression model was then constructed to evaluate factors associated with anesthetic conversion. The dependent variable was anesthetic conversion, modeled as a binary outcome. Independent variables included patient demographics (age, gender, race, and ethnicity), comorbidities (obesity, diabetes, dialysis status, CAD, prior CHF, CKD, COPD, prior CABG/PCI), procedural urgency, and medication use (preoperative beta-blocker, angiotensin-converting enzyme inhibitor/angiotensin II receptor blockers (ACE-I/ARB), aspirin, anticoagulation, P2Y12 inhibitor, and statin use). The model also adjusted for preoperative stenosis severity. Confounders were selected through backward stepwise regression ($P < 0.1$) and based on clinical relevance. A nomogram was developed to predict the likelihood of anesthetic conversion using significant variables identified in the multivariable logistic regression model.

Stata MP version 17.0 was used to combine datasets and define variables. All subsequent statistical analyses were performed using R version 4.3.1 (<http://www.r-project.org>). All tests were 2-sided and P values < 0.05 were considered significant.

RESULTS

A total of 58,960 TCAR cases were included in the final analysis, with 6,831 (11.6%) patients undergoing LRA, 51,851 (87.9%) receiving GA, and 278

(0.5%) requiring conversion from LRA to GA. Age demonstrated a significant association with conversion risk, with the greatest change in odds of conversion occurring at age 90. Additionally, patients who experienced anesthetic conversion were had higher rates of CAD, COPD, obesity, were more frequently prescribed preoperative medications, and were more likely to undergo urgent or emergent procedures compared to LRA or GA patients (Table I).

Multivariable analysis demonstrated that, compared to LRA, conversion to GA was associated with significantly higher odds of adverse outcomes, with notable increases in event rates. Specifically, conversion to GA resulted in higher rates of in-hospital stroke (3.2% vs. 1.2%, adjusted odds ratio [aOR] = 2.75; 95% CI, 1.27–5.28; $P = 0.005$), in-hospital death (2.2% vs. 0.4%, aOR = 5.03; 95% CI, 1.66–12.5; $P = 0.001$), perioperative MI (1.4% vs. 0.4%, aOR = 3.62; 95% CI, 1.06–9.36; $P = 0.017$), stroke/death (4.7% vs. 1.5%, aOR = 3.01; 95% CI, 1.54–5.36; $P < 0.001$), stroke/death/MI (5.4% vs. 1.8%, aOR = 2.92; 95% CI, 1.58–5.00; $P < 0.001$), and prolonged hospital length of stay > 2 days (34.9% vs. 27.8%, aOR = 1.38; 95% CI, 1.05–1.80; $P = 0.020$) (Table II). Similarly, when compared directly with GA, anesthetic conversion also showed higher rates of adverse events, including in-hospital stroke (3.2% vs. 1.3%, aOR = 2.54; 95% CI, 1.20–4.69; $P = 0.007$), in-hospital death (2.2% vs. 0.4%, aOR = 4.80; 95% CI, 1.66–10.9; $P < 0.001$), perioperative MI (1.4% vs. 0.4%, aOR = 3.24; 95% CI, 1.01–7.73; $P = 0.021$), stroke/death (4.7% vs. 1.5%, aOR = 2.95; 95% CI, 1.55–5.09; $P < 0.001$), and stroke/death/MI (5.4% vs. 1.9%, aOR = 2.75; 95% CI, 1.52–4.57; $P < 0.001$). In contrast, no significant differences in major outcomes were observed between patients undergoing LRA and those receiving GA, except for an increased likelihood of prolonged hospital stay in the GA group. When evaluating preoperative factors associated with conversion to GA, age (aOR = 1.02; 95% CI, 1.01–1.04; $P = 0.005$) and emergent procedures (aOR = 5.47; 95% CI, 1.34–14.7; $P = 0.004$) were identified as significant risk factors (Table III).

DISCUSSION

As the use of TCAR has dramatically increased over the last decade, there has been an increase in focus on identifying patient-specific and procedural variables influencing adverse outcomes for atherosclerotic carotid artery disease patients in relation to CEA and TFCAS.⁴⁻⁶ However, there has been less

Table I. Baseline demographic and clinical characteristics stratified by anesthesia status in TCAR patients

Demographic Variable	Local/Regional (N = 6,831)	General (N = 51,851)	Conversion ^a (N = 278)	P value
Mean age (Std)	74.0 (8.51)	73.4 (8.53)	74.6 (9.11)	<0.001
Sex: Female	2,439 (35.7%)	19,587 (37.8%)	100 (36.0%)	0.004
Race: White	6,074 (88.9%)	46,577 (89.8%)	245 (88.1%)	0.006
Hispanic	281 (4.1%)	2,294 (4.4%)	16 (5.8%)	0.257
Obese	2,087 (30.6%)	17,230 (33.2%)	100 (36.0%)	<0.001
Diabetes	2,689 (39.4%)	20,309 (39.2%)	113 (40.6%)	0.842
CAD	3,843 (56.3%)	27,584 (53.2%)	159 (57.2%)	<0.001
Prior CHF	1,275 (18.7%)	8,345 (16.1%)	52 (18.7%)	<0.001
COPD	1,673 (24.5%)	12,635 (24.4%)	75 (27.0%)	0.600
CKD	2,722 (39.8%)	20,023 (38.6%)	105 (37.8%)	0.150
CABG or PCI	1,673 (24.5%)	12,635 (24.4%)	75 (27.0%)	0.078
Prior Contralateral CEA/CAS	1,062 (15.5%)	8,439 (16.3%)	40 (14.4%)	0.241
Prior Ipsilateral CEA/CAS	675 (9.9%)	6,221 (12.0%)	33 (11.9%)	<0.001
Stenosis (>80%)	3,236 (47.4%)	23,858 (46.0%)	124 (44.6%)	0.054
Urgent Procedures	754 (11.0%)	6,098 (11.8%)	35 (12.6%)	0.011
Emergent Procedures	23 (0.3%)	113 (0.2%)	3 (1.1%)	0.011
Preop Betablocker	3,754 (55.0%)	27,561 (53.2%)	161 (57.9%)	0.010
Preop ACE inhibitor/ARB	3,462 (50.7%)	28,453 (54.9%)	163 (58.6%)	<0.001
Preop Aspirin	6,182 (90.5%)	46,535 (89.7%)	253 (91.0%)	0.124
Preop Anticoagulant	258 (3.8%)	2,056 (4.0%)	14 (5.0%)	0.502
Preop P2Y12-I	6,217 (91.0%)	46,271 (89.2%)	255 (91.7%)	<0.001
Preop Statin	6,206 (90.9%)	46,726 (90.1%)	256 (92.1%)	0.112

^aConversion: from Local/Regional to General anesthesia.

emphasis on identifying differences inherent to only TCAR procedures, such as with anesthesia choice.

Current literature on the impact of anesthesia techniques on carotid revascularization outcomes is controversial and often site-dependent, while data on TCAR remain limited. Previous studies examining anesthesia type on stroke or MI for CEA yield mixed outcomes, with some reporting no differences between LRA and GA and others finding an increased risk of stroke/MI with general anesthesia use.^{19–22} However, when comparing TCAR and CEA/TFCAS, most studies find that TCAR with GA is protective against MI. In a VQI study examining TCAR and CEA outcomes by LRA or GA, TCAR performed under GA was associated with significantly reduced risk of MI relative to CEA performed under GA for symptomatic patients. However, there was no direct comparison of TCAR performed under LRA versus GA; additionally, there was also no report of anesthesia conversion in either TCAR or CEA.¹⁰ A national study using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database comparing all carotid artery stenting procedure outcomes based on anesthesia type found that patients who underwent general anesthesia had decreased

odds of postoperative MI, but no difference in the odds of composite variable stroke, MI, or death. This study also lacked a TCAR-specific analysis, and conversions from LRA to GA were not identified within their database.²³

Similarly, studies on TCAR have reported mixed results regarding the impact of anesthesia modality on outcomes. A TCAR-specific analysis of the ACS NSQIP found that monitored anesthesia care (MAC), including LRA, was used in 73% of cases, while the remainder received GA. They additionally reported reduced odds of 30-day mortality, prolonged procedure time, or extended length of hospital stay for MAC versus GA.²⁴ However, another national study using VQI TCAR surveillance project data of LRA versus GA found there to be no significant differences in composite stroke/death/MI though 83% of cases were done with GA.²⁵ Neither analysis included information on anesthesia conversion rates or potential associated outcomes, which is a novel finding we present.

Using the VQI CAS cohort, we found that GA was the most common anesthesia choice, used in 88% of studied TCAR cases, which aligns with other current analyses of anesthesia trends.^{25,26} Conversion from LRA to GA was rare in our population, occurring

Table II. TCAR outcomes stratified by anesthesia status

Outcome	Conversion vs local/Regional			Conversion vs general			General vs local/Regional		
	Local/Regional	Conversion	aOR (CI)	P value	General	aOR (CI)	P value	aOR (CI)	P value
In-hospital stroke	1.2%	3.2%	2.75 (1.27–5.28)	0.005	1.3%	2.54 (1.20–4.69)	0.007	1.08 (0.86–1.38)	0.500
In-hospital death	0.4%	2.2%	5.03 (1.66–12.5)	0.001	0.4%	4.80 (1.66–10.9)	<0.001	1.04 (0.69–1.64)	0.900
Perioperative MI	0.4%	1.4%	3.62 (1.06–9.36)	0.017	0.4%	3.24 (1.01–7.73)	0.021	1.09 (0.75–1.66)	0.700
Stroke or death	1.5%	4.7%	3.01 (1.54–5.36)	<0.001	1.5%	2.95 (1.55–5.09)	<0.001	1.01 (0.82–1.26)	>0.9
Stroke, death, MI	1.8%	5.4%	2.92 (1.58–5.00)	<0.001	1.9%	2.75 (1.52–4.57)	<0.001	1.05 (0.87–1.28)	0.600
Extended length of stay ≥ 2 days	27.8%	34.9%	1.38 (1.05–1.80)	0.020	29.5%	1.23 (0.94–1.60)	0.120	1.12 (1.05–1.19)	<0.001

Table III. Preoperative factors associated with conversion of local to general anesthesia in TFCAS patients

Demographic variable	aOR	95% CI	P value
Age	1.02	1.01, 1.04	0.005
Obese	1.17	0.90, 1.51	0.200
Female	0.94	0.72, 1.21	0.600
White	0.96	0.50, 1.65	0.900
Hispanic	1.28	0.72, 2.13	0.400
Diabetes	1.01	0.78, 1.31	>0.9
CAD	1.01	0.69, 1.44	>0.9
Prior CHF	1.06	0.76, 1.47	0.700
COPD	1.19	0.90, 1.56	0.200
CKD	0.91	0.70, 1.17	0.500
CABG PCI	1.08	0.75, 1.57	0.700
Prior contralateral CEA/CAS	0.88	0.61, 1.22	0.500
Prior ipsilateral CEA/CAS	1.00	0.67, 1.45	>0.9
Stenosis (>80%)	0.96	0.75, 1.22	0.700
Urgent procedures	1.02	0.69, 1.46	>0.9
Emergent procedures	5.47	1.34, 14.7	0.004
Preoperative betablocker	1.10	0.84, 1.43	0.500
Preoperative ACE inhibitor/ARB	1.08	0.85, 1.39	0.500
Preoperative aspirin	1.10	0.73, 1.74	0.600
Preoperative anticoagulant	1.22	0.66, 2.06	0.500
Preoperative P2Y12-I	1.31	0.85, 2.10	0.200
Preoperative Statin	1.19	0.78, 1.93	0.400

in less than 1% of patients. However, conversion patients were significantly more likely than LRA or GA patients to be older, obese with history of CAD and COPD and use preoperative medications including beta-blockers, ACE-I/ARB, and P2Y12 antagonists. Both age and procedure urgency were significantly associated with increased odds of anesthesia conversion in our analysis. One potential explanation is that increasing age is associated with diminished cardiopulmonary function, altered anesthetic pharmacodynamics, and a greater burden of comorbidities, which together may reduce tolerance to procedural stress and light sedation.²⁷ Consequently, older patients undergoing TCAR under local anesthesia may be more likely to experience hemodynamic instability, agitation, or inadequate analgesia, prompting conversion to general anesthesia. In parallel, urgent TCAR cases are often performed under conditions of heightened physiologic stress, incomplete preoperative optimization, and limited opportunity for careful titration or confirmation of adequate local or regional anesthesia. These factors may increase the likelihood of pain, anxiety,

or instability during the procedure, necessitating conversion to general anesthesia to maintain patient safety and procedural control.²⁸

When comparing GA to LRA alone, GA use increased the odds of a prolonged hospital stay but did not significantly increase odds of in-hospital stroke, death, or perioperative MI, corroborating other TCAR-specific anesthesia study findings.^{25,26} Importantly, our study found that anesthesia conversion is associated with increased odds of in-hospital stroke, death, and postoperative MI compared to both GA and LRA. LRA to GA conversion also led to increased odds of longer hospital stays relative to LRA patients, but not to GA patients. Given that the increased odds of adverse outcomes were unique to patients who required anesthesia conversion, it may be clinically beneficial to proceed with GA rather than LRA, depending on the patient's age and the urgency of the procedure, in order to prevent the need for anesthesia conversion mid-procedure.

This study is limited by its retrospective design, which introduces selection bias and precludes the ability to establish causation. Additionally, inherent limitations of the VQI database include the absence of granular variables such as the rationale for anesthesia conversion and specific intra-procedural management strategies. For example, intraoperative stroke may necessitate conversion rather than result from it; however, the database does not distinguish between these scenarios. Similarly, factors such as failed regional block or patient discomfort may contribute to conversion without directly impacting outcomes. Furthermore, the relatively low incidence of anesthesia conversion in our cohort may limit the generalizability of our findings, particularly for low-volume centers. Despite these limitations, we have identified potential predictors of increased conversion risk, which may help guide anesthesia-related decision-making and improve postoperative outcomes in at-risk populations. Future prospective studies incorporating detailed intraoperative data are needed to elucidate the causal relationship between anesthetic conversion and adverse outcomes.

CONCLUSION

This study demonstrates that conversion from LRA to GA during TCAR is associated with significantly worse outcomes, including higher rates of stroke, death, and MI, compared to cases that remained under LRA or GA. Notably, age and emergent status were identified as significant preoperative risk

factors for conversion, emphasizing the need for thorough preoperative assessment and strategic anesthesia planning to mitigate the risk of conversion and improve patient outcomes.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Sabrina Straus: Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nyah Patel:** Writing – original draft. **Sina Zarrintan:** Writing – review & editing, Methodology, Conceptualization. **Marc Schermerhorn:** Writing – review & editing, Methodology. **Mahmoud Malas:** Writing – review & editing, Supervision, Methodology.

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