Transcarotid Artery Revascularization

Versus Carotid Endarterectomy Based on Safety and Efficacy

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Abstract:

Objectives:

- Objective 1: This paper challenges the use of carotid endarterectomy (CEA), an invasive vascular surgery, as a primary default to treating carotid stenosis by reviewing studies involving transcarotid artery revascularization (TCAR), CEA, and their post-procedure stroke, myocardial infarction, and cranial nerve injury rates.
- Objective 2: This paper addresses the pathophysiology and risk factors of carotid artery disease and the indications for intervention, whether it be TCAR or CEA.
- Objective 3: This paper describes the perioperative steps during TCAR and CEA.
- Objective 4: This paper compares operative times, perioperative blood loss, and postoperative length of stay associated with CEA and TCAR.
- Objective 5: This paper briefly reviews the cost-effectiveness of TCAR and CEA in relation to long-term financial benefit for patients with minimal current data available.

Methods: Studies comparing patients who underwent TCAR versus CEA were taken from EBSCO, ClinicalKEY, and Pubmed. A formalized literature search strategy narrowed the results to ten relevant studies conducted within the last decade. Meta-analysis was utilized when acceptable. Some of the articles outlined specific baseline comorbidities prior to comparing the two groups, while others chose to differentiate based on a symptomatic and asymptomatic basis.

Results: Inpatient and post-discharge CVA/death rates were comparable between TCAR and CEA. However, TCAR resulted in reduced risk of cranial nerve injuries compared to CEA and was found to have been associated with less operative times, blood loss, and shorter postoperative length of stay.

Conclusion: Transcarotid artery revascularization (TCAR) could present as a safer alternative to carotid endarterectomy (CEA) for specific patients with high-level carotid artery stenosis.

Introduction:

Stroke (CVA) is the fifth main cause of death and a major risk factor for long-term disability.[1] Ischemic strokes are the most common type of strokes. Approximately thirty percent of ischemic strokes are a result of atherosclerosis of the carotid arteries.[1] This progressive buildup of plaque imposes a blockage in the carotid artery leading to the brain. Risk factors for carotid artery stenosis include dyslipidemia, high blood pressure, diabetes, obesity, cigarette smoking, family history, age, and lack of exercise.[2] Medical management and lifestyle changes may be initiated first. However, when arteriography shows high-grade stenosis, consisting between 70-99% occlusion, operative treatments such as an open surgical carotid endarterectomy (CEA) or endovascular intervention may be recommended to mitigate the risk of an ipsilateral carotid stroke. Patients with symptomatic stenosis involving 50-69% occlusion gain moderate benefit from intervention. Surgery is not recommended for mild stenosis of less than 50% occlusion. Large, randomized studies have shown benefits from carotid intervention if the ipsilateral carotid artery has a stenosis of more than 70% after complete recovery following a transient ischemic attack or stroke.[3]

Current treatment options present problems of their own. CEA has been considered the gold standard intervention for the treatment of carotid disease since the 1950's, when it was created by Dr. Michael DeBakey.[4] Despite the fact that CEA is an accepted intervention for patients with asymptomatic and symptomatic carotid artery stenosis, it carries a 1-2% risk of permanent cranial nerve injury, 1-2% risk of postoperative neck hematoma, and 2-6% risk of postoperative myocardial infarction, according to the 2010 CREST study.[3] Transfemoral carotid artery stenting was developed as a minimally invasive alternative to CEA but has shown a 3.1% increased risk of perioperative CVA and death when compared to CEA.[5] This increased risk with transfemoral carotid artery stenting has prevented it from becoming universally accepted as an alternative for CEA in high-risk patients.[6]

Recently, transcarotid artery revascularization (TCAR) was offered as a clinically proven, less invasive alternative procedure to CEA. During the operation, the surgeon directly accesses the common carotid artery through a carotid cut-down approach, avoiding manipulation of the aortic arch.[1] The brain is protected through temporary blood flow reversal, which prevents the plaque from breaking off and causes dangerous embolisms during the operation. Studies show that TCAR is not problematic despite reversed blood flow because the brain is supplied by multiple arteries which maintain cerebral blood flow throughout the procedure. This novel carotid intervention may combine the safety of a carotid endarterectomy with the lesser morbidity of a transfemoral carotid stent and is aided by growing evidence of effectiveness in high-risk patients in need of revascularization.[7]

The Society for Vascular Surgery Vascular Quality Initiative TCAR Surveillance Project (TSP) was formed in association with the Centers for Medicare and Medicaid Services and the U.S. Food and Drug Administration to assess the safety and benefits of TCAR in hospital practices.[1] Prior research studies on TCAR have resulted in reduced CVA and death rates, but most studies did not consist of propensity-matched subjects.[8] This paper compares several studies' postoperative outcomes between patients receiving TCAR and those receiving CEA for symptomatic/asymptomatic carotid artery stenosis. This paper assesses whether similar patients undergoing either TCAR or CEA have equivalent rates of postoperative CVA, death, cranial nerve injury, and myocardial infarction (MI). The data is beneficial to surgeons in order to evaluate the most effective therapeutic intervention in patients presenting with carotid artery disease.

Description of TCAR:

The TCAR procedure requires the placement of a small transverse incision above the upper collarbone at the base of the neck. This allows proper exposure of the common carotid artery. A micropuncture needle, wire, and arterial sheath allow vascular access. An angiogram confirms the anatomy.[8] A wire is then placed into the external carotid for placement of the ENROUTE sheath, which allows operative control over the blood flow rate throughout the procedure. Femoral vein access is established, and a sheath is introduced, which helps complete the external pressure circuit. The common carotid artery is secured proximal to the sheath placement, which causes reverse blood flow. With flow reversal established, the conformable transcarotid stent is utilized to stabilize the plaque along the arterial wall, and a wire crosses the lesion. A predilated balloon angioplasty catheter can also be used if expansion of the stent is necessary. Once the stent is established, the clamp is loosened, and the sheath is removed. Blood flow is reversed back to its normal pathway, and the vessel is closed.[8] The delivery of these devices can disrupt the plaque and cause dangerous debris to be loose. Therefore, a filter is necessary to offer neuroprotection during the procedure.

Description of CEA:

An incision is made along the neck over the diseased carotid artery to expose the blocked area. A temporary, flexible tube is inserted into the artery so blood flow can resume around the blocked area.[9] Finally, the surgeon cuts into the affected artery and removes the plaque. The incision is closed with stitches.[10]

Methods:

Pubmed, EBSCO, and ClinicalKey were searched for studies comparing the outcomes of patients with carotid artery disease who were treated with TCAR or CEA. Meta-analysis was conducted when appropriate. Using the three electronic databases mentioned above, the studies were selected by searching the following key terms: "transcarotid artery revascularization, carotid endarterectomy, safety, efficacy, versus, outcomes." The search terms were then crossed and combined to perform a more advanced search. From there, a detailed reading and critical analysis of each article were performed. Duplicated articles were removed. Each study was classified based on its study design (i.e., systematic reviews, case control, randomized control trials, cohort studies, etc.) and methodological quality. The literature searches from all three databases resulted in ten articles.

An initial literature search was performed in September 2021 using PubMed database using the search terms, "transcarotid artery revascularization" and "carotid endarterectomy," which yielded eight results. Search parameters for "Full Text and MEDLINE" and "outcomes" were added to further focus the literature search, which led to six articles. Articles were further extracted based on the inclusion or exclusion of comparison between the two cardiologic interventions. This focused search criteria refined the search to five articles. These five articles were included because they addressed the comparison between TCAR and CEA in a hospital setting for patients with carotid artery disease.

An additional search was performed in October 2021 using the Clinical Key database with the search terms "transcarotid artery revascularization" and "carotid endarterectomy", which yielded 3896 results. Search parameters for "full free text" and "outcome" and "safety" were added to simplify the results to ten articles. From these ten articles, five of them did not address the comparison between the safety profile between CEA and TCAR. Three other articles did not offer full-text access. The remaining two articles were chosen to define the comparison between the two cardiologic interventions.

An additional search was conducted in October 2021 using EBSCO database with the same search terms "transcarotid artery revascularization" and "carotid endarterectomy" and "outcomes." These search terms generated fifty results. To narrow the search results, the terms "open access" and "versus" were added. This resulted in six articles. Of those articles, three were relevant to the study. The articles excluded either did not compare CEA and TCAR, were repeats from previous databases, or were repeats themselves.

Results:

After thorough evaluation of the ten articles collected, the individual studies below resulted in similar findings, despite differences in methods and statistical analysis variables.

Many of the studies assessed the rates of postoperative myocardial infarction between the two cardiologic interventions. A systematic review and meta-analysis conducted by Cui et al.[6] was carried out through nine randomized studies assessing 4012 patients undergoing TCAR. No significant contrast in the 30-day risk of myocardial infarction was found when comparing TCAR and CEA.[6]

Dakour-Aridi et al.[1] conducted a study published in *Seminars in Vascular Surgery* comparing inpatient and 1-year outcomes between CEA and TCAR intervention in symptomatic/asymptomatic patients with diagnosed carotid disease. The study included 4,122 patients undergoing TCAR and 55,373 patients undergoing CEA. Every patient was assessed for pre-existing characteristics and comorbidities. TCAR resulted in notably reduced rates of inpatient myocardial infarction (OR=0.44; 95% CI, 0.25 to 0.76; P < 0.01).[1]

Another factor to consider is stroke rates when comparing TCAR and CEA. A multi-institutional analysis comparing the two cardiologic interventions conducted by Kashyap et al.[8] matched the patients in the study in a 1:1 (CEA: TCAR) fashion regarding preexisting comorbidities, such as age, sex, symptom status, and diabetes. Stroke (1.0% TCAR vs 0.3% CEA; P=0.62)[8] rates were similar at 30-days and comparable at 1-year post operation (CVA, 2.8% vs 2.2% [P=0.79]).[8]

Yee et al.[7] performed a retrospective study between January 2011 and July 2018 involving patients undergoing TCAR or CEA at the Indiana University School of Medicine Institution. Participants were propensity-matched by any of the following: age, sex, BMI, tobacco use, restenosis, prior history of neck radiation, contralateral carotid disease, prior neck dissection, and symptom status.[7] A summative incidence rate of CVA/death was similar for both TCAR and CEA (2.42; [-0.57, 5.41], P=0.11).[7]

Schermerhorn et al.[11] contrasted inpatient results of TCAR and CEA by assessing patients who underwent TCAR and CEA between January 2016 to March 2018 using the Society for Vascular Surgery Vascular Quality Initiative TCAR Surveillance Project registry and the Society for Vascular Surgery Vascular Quality Initiative CEA database.[11] 1182 patients received TCAR, while 10,797 patients underwent CEA. Patients who received TCAR were older on average and at a greater risk of being symptomatic.[11] The TCAR patients had more preexisting comorbidities, including coronary artery disease, congestive heart failure, chronic obstructive pulmonary disease, and chronic kidney disease. When analysis was adjusted, TCAR was associated with comparable rates of inpatient CVA/death (1.6% vs 1.4%, P=0.33)[11] and CVA/death/MI (MI; 2.5% vs 1.9%, P=0.16)[11] to CEA. No differences were observed in rates of CVA (1.4% vs 1.2%, P=0.68).[11]

Mehta et al.[12] conducted a study focusing on elderly patients, also known as octogenarians. This group of individuals included patients with the following: a variety of pre-existing comorbidities, reduced functional capacities, and increased risks with anesthesia when compared to their younger cohorts.[12] Octogenarians resulted in the greatest 30-day and 1-year CVA/death rates when compared to their younger groups (2.3% and 6.3%).[12] Of all the patients, the modified risks of TCAR in relation to CEA were close for 30-day CVA/death and mildly increased for 1-year CVA/death.[12]

The following studies assessed the risk of cranial nerve injury when performing TCAR and CEA. Four of the studies included in the systemic review by Cui et al.[6] showed a reduction in cranial nerve injury with TCAR when compared to CEA (0.54% and 1.84%).[6] The multi-institutional analysis by Kashyap et al.[8] correlated TCAR with a decreased rate of cranial nerve injury when compared to CEA (0.3% vs 3.8%; P=0.01).[8] Additionally, the retrospective study by Yee et al.[7] resulted in less risk of cranial nerve injury with TCAR than with CEA (0% versus 6.9%, P= 0.01),[7] even though there were more patients receiving TCAR with a prior history of a ipsilateral neck dissection (6.9 % versus 1.2%)[7] and radiation (6.9% versus 0%).[7]

Columbo et al.[13] conducted a comparative-effective research study to analyze the benefits of adopting TCAR over CEA. The data utilized in this study was collected between the years 2015 to 2019 from the Vascular Quality Initiative registry. This study associated TCAR with lower risk of nerve injury than CEA (19 patients [0.2%] vs 2041 patients [2.6%]; P< 0.001).[13]

The following studies compared the duration of hospital stays with TCAR and CEA. The study performed by Dakour-Aridi et al.[1] showed patients receiving TCAR were more likely to be discharged after one day (OR=0.74; 95% CI, 0.64 to 0.85; P < 0.001).[1] The study by Schermerhorn et al.[11] showed TCAR patients had less risk for cranial nerve injury (0.6% vs 1.8%, P < 0.001)[11] and were more likely to leave within one day after the procedure (27% vs 30%, P=0.046).[11]

The amount of operative time and blood loss were compared between the two cardiologic interventions. The study performed by Schermerhorn et al.[11] showed TCAR required 33 minutes less than CEA (78 +/- 33 min vs 111 +/- 43 min; P < 0.001).[11]

Yee et al.[7] utilized multivariate analysis. Results showed that TCAR was associated with an increased risk of intraoperative hypertension, decreased reverse flow/clamp time (mins; -36.80; [-45.47, -27.93], $P < 0.01$),[7] and estimated blood loss (mLs; -63.66; [-85.91, -41.42], $P < 0.01$).[7] These results suggest that TCAR and CEA are equivalent in the perioperative period, while TCAR is associated with less operative time and blood loss.

The study by Columbo et al.[13] associated TCAR with shorter operative time when compared to CEA (67[53-86] minutes vs 108 [85-137] minutes; $P < 0.001$).[13]

Limitations:

The multi-institutional analysis performed by Kashyap et al.[8] was the only one of the studies assessed that utilized propensity matching. By matching TCAR with CEA patients in a 1:1 fashion, the clinical variables that differentiate TCAR vs CEA are reduced.[8] It is difficult to assess the comparison between TCAR and CEA because most of the patients undergoing TCAR have underlying significant comorbidities such as older age, underlying COPD, chronic kidney disease, and heart disease, which deny them the option of CEA due to their poor surgical candidacy. Therefore, unless the patient populations between the two groups are based on a 1:1 propensity matching, the results are not as conclusive.

Whether or not the operations were performed by varying experienced-level surgeons could have skewed the data in favor of one intervention over the other. Some of the studies involved surgeons who were experienced in transfemoral carotid artery stenting and CEA before initiating TCAR, which could have affected the results. Typically, TCAR is performed by vascular surgeons and success rates could vary depending on the type of surgeon performing the operation. Of the studies evaluated, no data was offered on a learning curve for TCAR.

All of the studies involved high-risk patients, which were defined by the criteria set forth by the Centers for Medicare and Medicaid Services only.[7] More data is needed in order to determine whether TCAR is effective on standard-risk or low-risk patients. It is unreasonable to suggest that TCAR can be utilized in all patients with carotid disease without studies representing all risk stratifications.[1] These studies were limited by reduced sample sizes and sampling bias, which may have manipulated the results. Whether or not the study involved symptomatic and/or asymptomatic patients could have affected the perioperative CVA/death/myocardial infarction rates, due to the patient's underlying baseline comorbidity prior to the procedure.

Most patients are discharged after one day post-operation with TCAR. It can be reasonably suggested that some adverse events could have occurred after the patients were discharged, which may not have been shown in some of the studies.[11] This is why it is important to include 30-day postoperative outcomes as well as in-hospital outcomes. A significant amount of major adverse cardiac events (MACE) can occur after discharge following carotid artery revascularization.[11]

The availability of CEA compared to TCAR is unequaled at this time. With growing access to this novel modality, it could be reasonably suggested that the results may change with better access, a better learning curve, and more experienced surgeons performing TCAR.

Confounding variables between the studies' samples including hospital resources, teaching affiliations, postoperative protocols, and other factors may need to be considered when determining the validity of the various studies.[12]

Discussion:

Patients considered to be a high-risk candidate for CEA consist of those with one of the following: a prior history of neck radiation/surgery, an immobile C-spine restricting access to anatomy, a lesion extending higher than C2, contralateral carotid disease, and an intolerance to general anesthesia due to cardiovascular comorbidities.[7] TCAR was developed as a secure alternative for patients who are not considered good surgical candidates for CEA. Since the introduction of TCAR, there has been up to 86% reduction in transfemoral carotid artery stenting at the Indiana University School of Medicine Institution.[7]

Another factor to consider is the cost-effectiveness of TCAR compared to CEA. A recent study conducted by Cui et al.[4] published in the Journal of Vascular Surgery in December 2021 found that, although 5-year costs for TCAR were $11,000 more than CEA, TCAR offered greater quality-adjusted life years (QALYs) and could be more economical in the long-term.[4] These results were gathered from a high-volume institute for carotid revascularization.[4] More economic studies are needed to contrast the cost-effectiveness of CEA and TCAR. Given the novelty of TCAR, it would be reasonable to conclude that the cost of this intervention will decrease with more wide-spread usage.

Whether or not the efficacy of TCAR compares to CEA in the treatment of carotid restenosis is important to consider in the high-risk population being studied. Several recent works have assessed the risk of restenosis after CEA, revealing a rate between 5-22% and an in-stent restenosis rate between 2.7-33%.[14] A study performed by Wang et al.[15] consisted of 237 TCARs executed at small, respected institutions. Of these cases, 55 stents were placed because of restenosis (47 CEA, 8 transfemoral carotid artery stenting).[15] Within 30 days of the operation, no additional CVAs or myocardial events occurred. In addition, there were zero cases of in-stent restenosis, thrombosis, or re-interventions. The results concluded that TCAR has the potential to treat patients with restenotic carotid disease with sustainable incidences of ipsilateral CVA, myocardial infarct, and death.[15]

Conclusion:

Despite the less-invasive approach associated with TCAR, inpatient and post-discharge CVA/death rates were comparable between TCAR and CEA. However, TCAR may mitigate the risk of cranial nerve injuries compared to CEA and was found to have been associated with less operative times and blood loss and shorter postoperative length of stay. Data suggests that TCAR is a safe alternative for CEA. Further comparative studies are warranted to confirm the similarity of TCAR vs CEA, with focus on longer-term follow up and greater sample sizes.

There are different indications for CEA and TCAR, which were previously addressed above. Therefore, it is important to consider which intervention would be the most appropriate on a patient-specific basis. The TCAR procedure is considered safe and effective; however, one must consider the level of experience most surgeons have performing it. Because of its minimal hospital availability when compared to CEA, the level of expertise with the procedure among surgeons overall may take some time to develop.

For providers in this growing career field, it is important to consider their roles in these revascularization procedures. Whether they play a vital role during the operation or during postoperative follow up, the rates of MACE can affect the providers, as well. This could increase stress levels and feelings of inadequacy when dealing with a novel modality. Therefore, it is important to both consider the patient's level of comfort and follow the intervention chosen by the providers.

TCAR requires more research, which will bring about more medical knowledge. Patient care and communication are important competencies required by practicing providers. With this new intervention, providers want to offer the most beneficial and safest option to each patient specifically while considering quality of care.

As invasive as cardiologic interventions are, it is vital that good communication exists between providers and patients prior to the initiation of surgery. Providers are required to advocate for quality patient care and optimal patient systems, while working effectively and coordinating appropriate patient care within their specialty.

Resources:

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