The utility of adjunctive electroencephalography while performing transcarotid artery revascularization

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ABSTRACT

Transcarotid artery revascularization (TCAR) has been used as an alternative to carotid endarterectomy and transfemoral carotid artery stenting. Although TCAR has been associated with a decrease in perioperative strokes compared with transfemoral carotid artery stenting, little is known about the safety of cerebral blood during flow reversal or the value of adjunctive electroencephalography (EEG) monitoring in performing TCAR. We describe two cases of EEG changes in patients undergoing TCAR. These cases highlight the use of adjunctive EEG and provide examples of test clamping to assess for compromised collateral cerebral blood flow in patients undergoing TCAR. (J Vasc Surg Cases and Innovative Techniques 2019;5:456-60.)

Keywords: Transcarotid artery revascularization; Electroencephalogram; Neuroprotection

Although carotid endarterectomy (CEA) has been the "gold standard" for the treatment of significant carotid artery stenosis, carotid artery stenting (CAS) has become a less invasive alternative that is considered for high-risk patients or those with complex anatomy.[1-3] However, CAS has been limited by the increased risk of stroke relative to CEA.[4-8] Transcarotid artery revascularization (TCAR) with the ENROUTE Transcarotid Neuroprotection System (Silk Road Medical, Sunnyvale, Calif) is an alternative to CEA that has been demonstrated to be safe and effective in protecting against embolic events.[9-15] TCAR uses flow reversal from the common carotid artery (CCA) into the femoral vein with a built in filter device to trap embolic plaque and debris. Blood flows through the circle of Willis from the contralateral carotid arteries to the internal carotid artery (ICA). We present two cases of significant changes on electroencephalography (EEG) during TCAR, which suggest that EEG may be a useful adjunct to identify areas of cerebral hypoperfusion. Informed consent for publication of these cases was obtained.

CASE REPORTS

Case 1. A 77-year-old man with a history of right (2009) and left (2013) CEA presented with asymptomatic high-grade stenosis of bilateral ICAs. Preoperative computed tomography angiography revealed >75% stenosis of the right ICA (Fig 1, *A*), a clavicle to bifurcation distance of 5.2 cm, no evidence of proximal CCA disease, and a complete circle of Willis (Fig 1, *B*). Because of advanced age and history of CEA, the patient was considered for a right TCAR under general anesthesia with EEG and somatosensory evoked potential monitoring. Baseline EEG showed symmetric alpha and theta waves without concerning findings (Fig 2, *A*). After clamping and 1 minute on high-flow reversal, the patient exhibited right-sided loss of amplitude, complexity, and activity on EEG monitoring (Fig 2, *B*). The CCA was unclamped, flow reversal was changed to low flow, and systolic blood pressure was increased (Fig 2, *C*). The EEG recording returned to baseline without additional adjunct measures. The CCA was clamped again, and similar EEG changes were again noted on the right side of the brain. After predilation with a 4.5- × 20-mm balloon, an 8- × 40-mm ENROUTE Transcarotid stent was deployed. The CCA was unclamped, the EEG recording improved instantly, and postoperatively the patient was grossly neurologically intact. Total clamp time was 4 minutes, and the total case time was 112 minutes.

Case 2. A 73-year-old man with a history of transient ischemic attack presented with high-grade left carotid stenosis. Preoperative computed tomography angiography revealed 80% to 90% stenosis in the left ICA (Fig 3, *A*), a clavicle to bifurcation distance of 7.3 cm, no evidence of proximal CCA disease, and a complete circle of Willis (Fig 3, *B*). Because of the patient's history of severe pulmonary disease, TCAR was advised over CEA. EEG with somatosensory evoked potential monitoring demonstrated a baseline without concerning findings (Fig 4, *A*). After a standard exposure, the CCA was clamped and active flow reversal commenced. Immediate EEG changes with loss of amplitude, complexity, and activity were noted (Fig 4, *B*). The flow reversal system was changed to the low-flow setting, blood pressure was optimized (Fig 4, *C*), and the EEG changes improved after the CCA was clamped for approximately 3 minutes without additional adjunctive measures. The lesion was then crossed,

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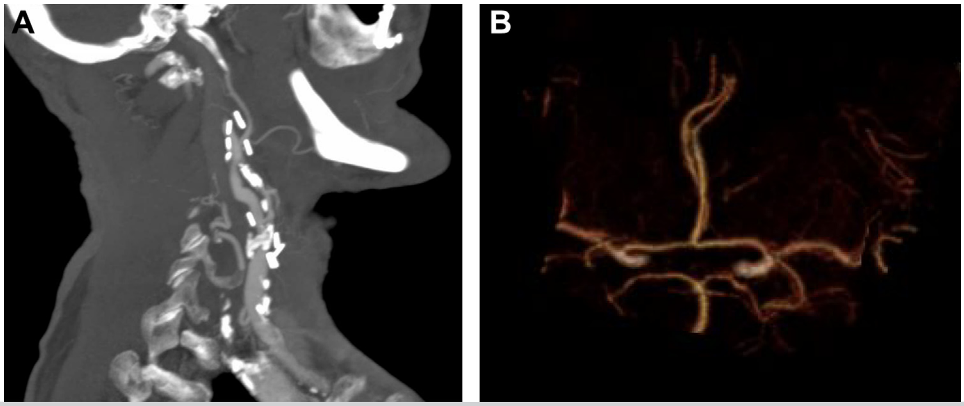

Fig 1. A, Maximum intensity projection of head and neck before transcarotid artery revascularization (TCAR) showing high-grade stenosis of the right internal carotid artery (ICA). **B,** Three-dimensional reconstructed computed tomography angiography image showing intact circle of Willis.

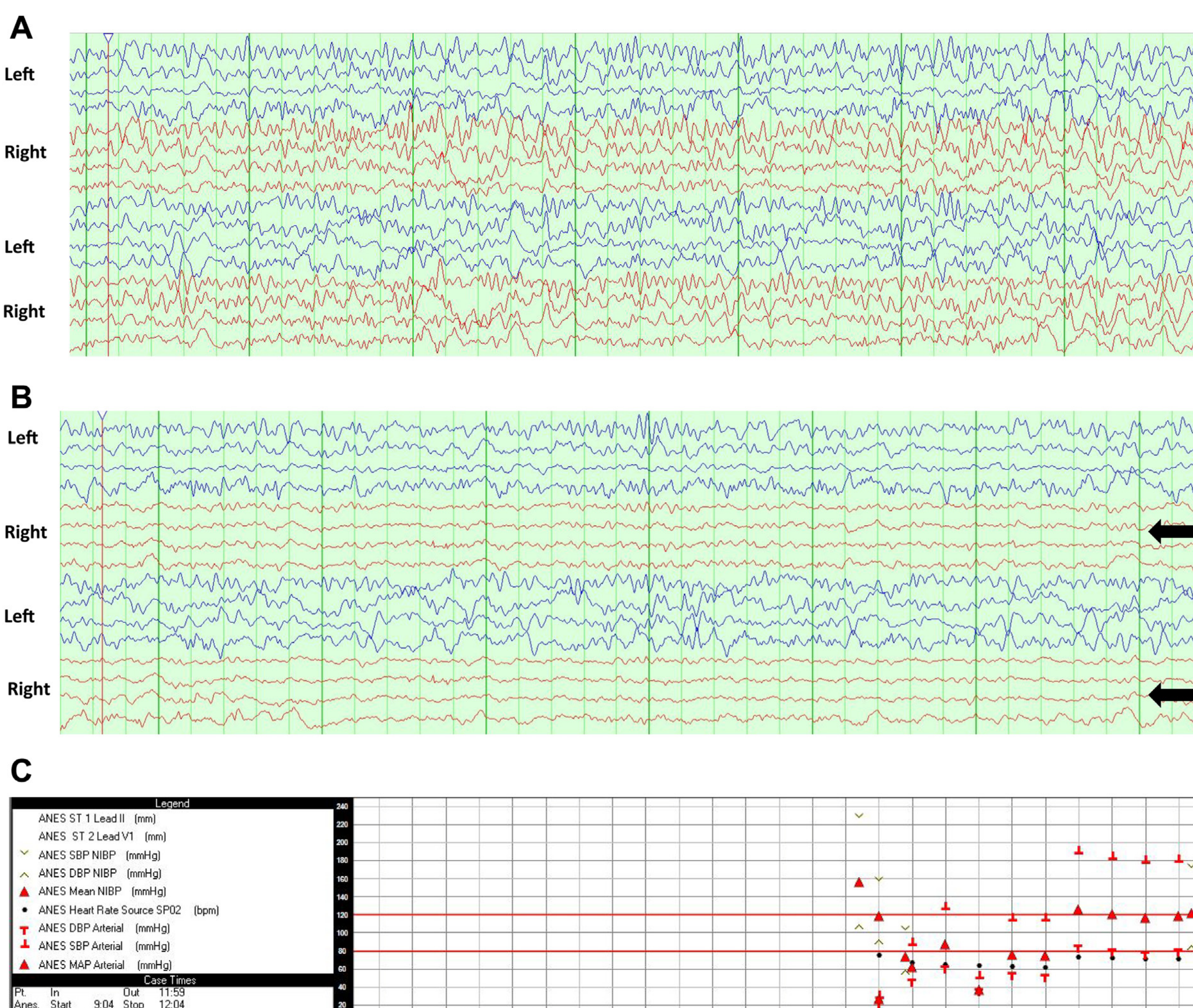

Fig 2. Electroencephalogram before **(A)** and after **(B)** clamping of the common carotid artery (CCA). The baseline electroencephalogram reveals symmetric alpha and theta waves from the left to the ride side. The *blue lines* depict activity of the left side of the brain; the *red line*s depict activity of the right side. After clamping of the CCA, a loss of amplitude and wave complexity was seen, reflecting changes on the right side of the brain (*arrow*). The anesthesia blood pressure tracing reveals augmentation of systolic blood pressure to approximately 180 mm Hg from 120 mm Hg **(C)**.

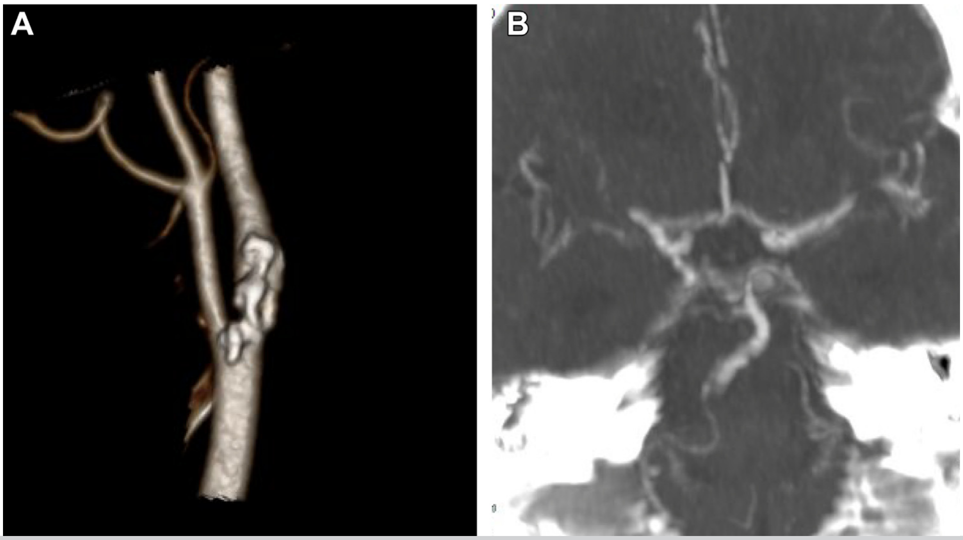

Fig 3. A, Three-dimensional reconstructed computed tomography angiography image of head and neck before transcarotid artery revascularization (TCAR) showing high-grade stenosis of the left internal carotid artery (ICA). **B,** Maximum intensity projection showing intact circle of Willis.

predilated with a 5- × 30-mm balloon, and stented with an 8- × 40-mm stent with fluctuating EEG changes noted. After 90 seconds, angiography was performed and demonstrated good stent apposition. Shortly after, the patient's EEG recording returned to baseline, and postoperatively the patient was grossly neurologically intact. Total clamp time was 11 minutes, and the total case time was 81 minutes.

DISCUSSION

The introduction of TCAR has been associated with a reduced operative stroke risk compared with transfemoral CAS.[8,11,14] However, there is a lack of literature regarding the utility of EEG monitoring as an adjunct to TCAR. Our cases highlight that adjunctive EEG during TCAR can be useful to assess compromised cerebral blood flow and lead to the implementation of maneuvers to mitigate the cerebral hypoperfusion that would not be detected or accounted for if EEG monitoring were not used.

Without adjunctive shunting, CEA has been associated with cerebral hypoperfusion during the period of blood flow interruption, with rates of intraoperative stroke estimated between 3% and 5%.[16-18] The use of EEG has been shown to decrease intraoperative stroke rates below 0.8% for CEA.[19,20] Clamping in CEA has been associated with EEG abnormalities, appearing in 14% to 49.1% of patients undergoing CEA.[19,21,22] Clamp-induced EEG changes usually occur within the first 4 to 5 minutes after cross-clamping and increase risk of long-term stroke up to six times.[21-23] In the Safety and Efficacy Study for Reverse Flow Used During Carotid Artery Stenting Procedure (ROADSTER), the mean flow reversal time for TCAR was 12.9 minutes.[11,24] Flow reversal leads to concern about cerebral perfusion for patients who do not have adequate circulation through the circle of Willis. Inadequate formation of collateral circulation may increase the risk of cerebral hypoperfusion during carotid clamping, and up to 91% of patients have a deviation from the normal circle of Willis anatomy.[25,26] Further studies are needed to elucidate the percentage of patients undergoing carotid interventions who have inadequate collateral circulation.

During carotid clamping for CEA, shunting can be quickly and reliably achieved if there are observed EEG changes, thereby mitigating prolonged cerebral hypoperfusion. During TCAR, the relatively longer time of flow reversal without a mechanism to reliably provide antegrade flow to the affected cerebral hemisphere does support the utility of regular use of EEG during TCAR. A post hoc analysis of the ROADSTER trial found that only 1.2% of patients exhibited slight EEG changes during flow reversal that resolved with blood pressure elevation, with the authors concluding that TCAR can be performed without the use of EEG.[24] Since 2017, our institution has performed 85 TCAR procedures with a stroke rate of 1.2% and overall stroke and death rate of 1.2%. In our experience with use of adjunctive EEG, two patients had EEG changes (2.35%). As demonstrated, the rate of significant EEG changes is currently greater than our stroke rate, and our outcomes may in part be attributed to the use of EEG with TCAR at our institution.

Based on our experiences, we recommend EEG with test clamping first to evaluate for EEG changes and to identify patients at risk of cerebral hypoperfusion. If EEG changes are present, augmentation of blood pressure before repeated clamping may help decrease cerebral hypoperfusion.[27] Furthermore, a trial of the low-flow setting on the flow reversal system may be used.[27] Other strategies include re-establishing antegrade flow by releasing control of the CCA clamp for 5 minutes before

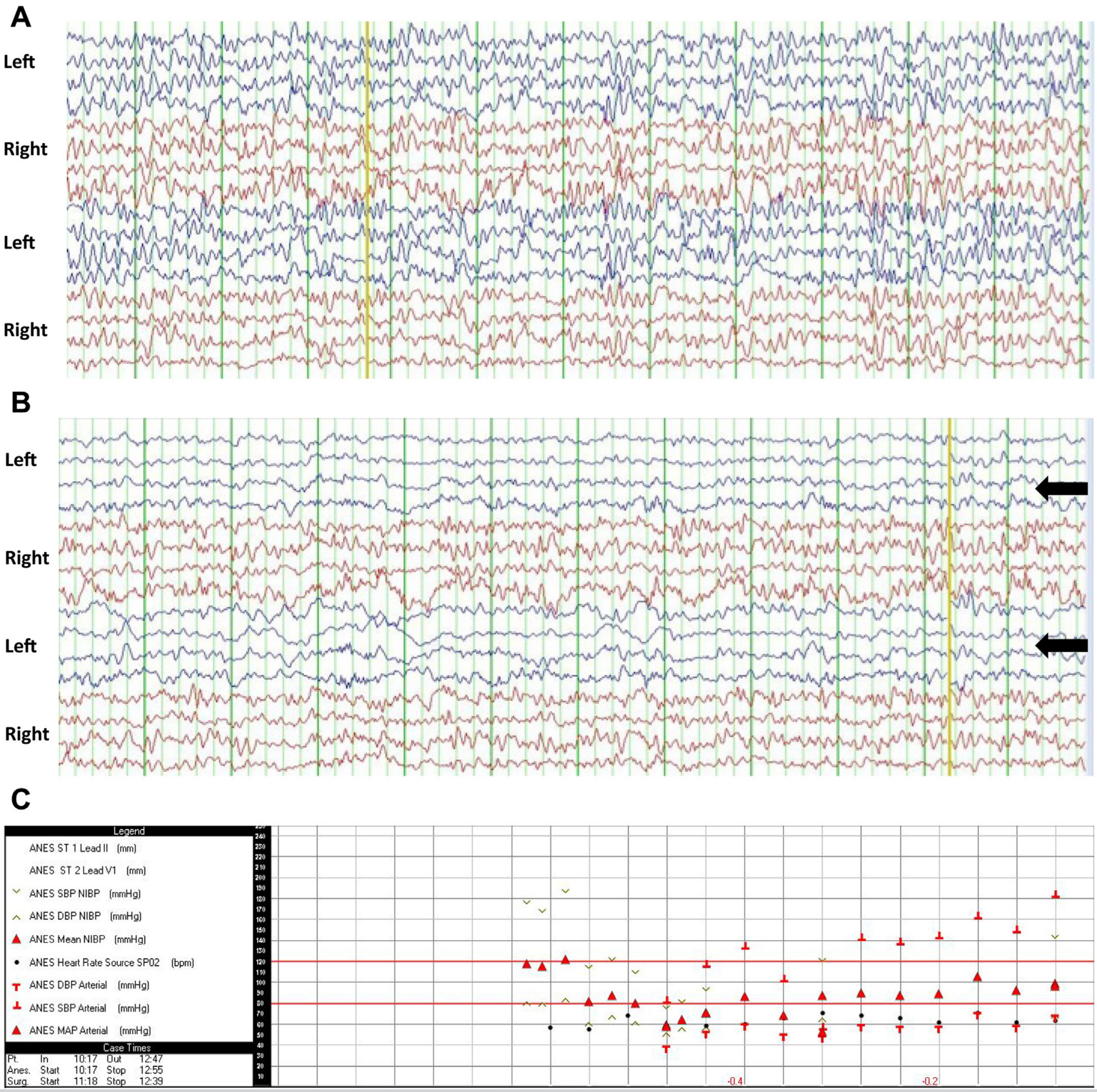

Fig 4. Electroencephalogram before **(A)** and after **(B)** clamping of the common carotid artery (CCA). The baseline electroencephalogram reveals symmetric alpha and theta waves from the left to the ride side. The *blue lines* depict activity of the left side of the brain; the *red lines* depict activity of the right side. After clamping of the CCA, a loss of amplitude and wave complexity was seen, reflecting changes on the left side of the brain (*arrow*). The anesthesia blood pressure tracing reveals augmentation of systolic blood pressure to approximately 150 mm Hg from 120 mm Hg **(C)**.

reclamping, preclamping the CCA before advancing the sheath, and using general anesthesia to decrease cerebral metabolic demand.[27] Last, if EEG changes are still severe, a decision must be made to continue in an expeditious manner or to abort the case.

CONCLUSIONS

There is a paucity of knowledge about the safety of cerebral blood flow reversal during TCAR. Patients undergoing TCAR rely on stroke protection by active flow reversal without a reliable and quick method of establishing antegrade cerebral perfusion. Flow reversal relies on intact collateral circulation through the circle of Willis. Most patients have a circle of Willis anatomy that differs from the normal anatomic configuration, but it is unknown how many patients undergoing carotid intervention have inadequate collateral circulation. These cases demonstrate the utility of EEG in patients undergoing TCAR to guide adjunctive measures to decrease cerebral hypoperfusion.

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