# Carotid Artery-Related Perioperative Stroke Following Anterior Cervical Spine Surgery: A Series of 3 Cases and Literature Review

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*Background:* Vascular complications following anterior cervical spine surgery are rare but potentially devastating. Complications associated with the carotid artery are even more disastrous but largely anecdotal, with no more than 4 reported cases. *Materials and Methods:* We report 3 new cases of carotid artery-related perioperative stroke following anterior cervical spine surgery. All 3 patients had carotid artery atherosclerosis and the time of intraoperative carotid artery retraction was longer than 1 hour. One patient underwent hypotension during surgery. Risk factors as well as prevention and management protocols of carotid artery-related perioperative stroke based on the literature review and our clinical experience are discussed. *Conclusions:* Carotid artery-related perioperative stroke following anterior cervical spine surgery is extremely rare. Prolonged traction, carotid artery atherosclerosis, and intraoperative hypotension can produce cerebral hypoperfusion and cause ischemic stroke. Preoperative risk assessment, adequate perioperative manipulation, and postoperative management can minimize overall morbidity and mortality.

**Key Words:** Cervical spine—anterior surgery—carotid artery—ischemic stroke—vascular complication



## Introduction

Anterior cervical spine surgery has been performed extensively for the treatment of degenerative spine diseases with relatively low rates of complications.[1-3] Vascular complications following anterior cervical surgery are rare but are potentially devastating and most frequently involve vertebral arteries.[4,5] Complications associated with the carotid artery are even more disastrous but largely anecdotal, with no more than 4 reported cases, and can lead to ischemic stroke, paralysis, and even death.[6-9] Identifying risk factors and proper management could reduce patient mortality and morbidity. However, only few publications have summarized this issue systematically and comprehensively in neurosurgical literature.[5,7,10] Herein, we report 3 new cases of carotid artery-related perioperative stroke following anterior cervical spine surgery, which is the largest series of cases reported to date. Risk factors as well as prevention and management protocols of carotid artery-related perioperative stroke based on the literature review and our clinical experience are discussed.

## Case Presentations

### *Case 1*

A 55-year-old male, with a medical history of atherosclerosis of the carotid and cerebral arteries, presented with numbness of upper left extremity. Preoperative

*Abbreviations:* ACCF, anterior cervical corpectomy and fusion; ACDF, anterior cervical discectomy and fusion; ADR, artificial disc replacement; CT, computed tomography; ICA, internal carotid artery; MCA, middle cerebral artery; MRI, magnetic resonance imaging

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neurologic examinations showed normal muscle power in all extremities, but sensation was diminished in the left arm while pathological reflex was positive. Magnetic resonance imaging (MRI) revealed disc herniation at C5-C6 and C6-C7 levels. He underwent anterior cervical discectomy and fusion (ACDF) at C5-C6 and C6-C7 levels through a right-sided approach. Intraoperatively, cervical self-retaining retractors were used to maintain exposure. The operative time was 1.5 hours, with 1 hour of retraction and 50 mL of blood loss. There were no adverse events such as intraoperative hypotension, hypertension, or hypoxia throughout the operation. Postoperatively, the numbness in his left arm was relieved. On the first day after surgery, the patient suddenly presented left hemiplegia and facial palsy. A diffusion-weighted MRI showed cerebral infarction of the right middle cerebral artery territory (Fig. 1A). Carotid Doppler ultrasound detected atherosclerotic lesions in the bilateral common carotid arteries. Then, a computed tomography (CT) angiography was performed and severe stenosis at the origin of the right middle cerebral artery was found (Fig. 1B). After blood pressure management, intravenous fluids, and oral antiplatelet treatment, he was discharged on the eighth postoperative day to the rehabilitation department. Muscle power of his left limbs improved to grade 4/5 at the 6-month follow-up, but facial palsy remained unchanged.

*Case 2*

An 80-year-old female presented with weakness of the left upper limb. She had a previous history of hypertension, diabetes, and paroxysmal atrial fibrillation. To maintain normal blood pressure and blood glucose, she received 5 mg of amlodipine once daily and 50 mg of acarbose 3 times daily. Preoperative neurologic examination revealed grade 4/5 power in the biceps and triceps of the left arm, while left arm reflexes were absent. Cervical MRI showed severe disc herniation at C4-C5 and C5-C6 levels and carotid Doppler ultrasound demonstrated atherosclerotic lesions in the bilateral common carotid arteries. She underwent C4-C5 and C5-C6 ACDF from the right side and self-retaining retractors were used for exposure. On the morning of the day of surgery, she received 5 mg of amlodipine and no other premedication. Operative time was 1.5 hours, with 60 minutes of retraction and 40 mL of blood loss. During the surgery, she experienced an episode of hypotension at a blood pressure of 90/60 mmHg, which was then corrected with rapid crystalloid infusion and noradrenaline. The blood pressure was maintained at around 140/90 mmHg till the end of surgery. Postoperatively, she developed weakness in the lower left limb with grade 1/5 muscle power. An urgent CT scan revealed no hematoma. A diffusion-weighted MRI showed cerebral infarction of the right corona radiata (Fig. 2A). Repeated carotid Doppler ultrasound demonstrated no thrombosis with normal blood flow. Transcranial Doppler ultrasound found normal blood flow in the cerebral arteries. Then, CT angiography of the carotid and cerebral arteries was performed and no thrombosis or artery stenosis was found. Repeat CT scan at 72 hours showed infarction of the right basal ganglia, corona radiata, and temporal lobe (Fig. 2, B,C). The patient was treated with blood pressure management, intravenous fluids, and oral antiplatelet treatment. After 3 months of rehabilitation, muscle power of her left leg improved to grade 3+/5.

*Case 3*

A 60-year-old male presented with weakness of bilateral lower limbs. He had a medical history of diabetes and cerebral infarction. He received low-dose aspirin (100 mg) for prevention before surgery and it was continued during the perioperative period. A preoperative neurologic examination revealed grade 4/5 power in both legs. The preoperative carotid Doppler ultrasound detected atherosclerotic lesions in the bilateral common carotid arteries. He was diagnosed with cervical spondylotic myelopathy and underwent ACDF at C3-C4, C5-C6, and C6-C7 levels through a right-sided approach. The

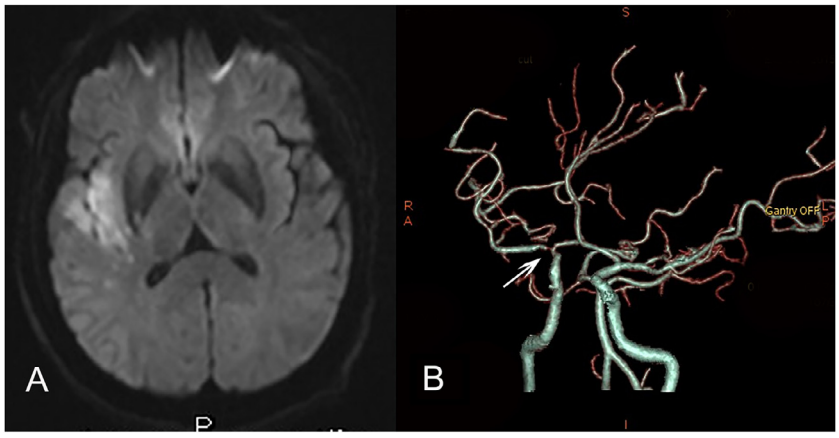


**Figure 1.** *Images from Case 1. (A) Postoperative diffusion-weighted magnetic resonance imaging showed cerebral infarction of the right middle cerebral artery territory. (B) Computed tomography angiography found severe stenosis at the origin of the right middle cerebral artery.*


**Figure 2.** *Images from Case 2. (A) Postoperative diffusion-weighted magnetic resonance imaging showed cerebral infarction of the right corona radiata. (B, and C) Repeat computed tomography scan at 72 hours showed infarction of the right basal ganglia, corona radiata, and temporal lobe.*

operative time was 2 hours, with 1.5 hours of retraction by self-retaining retractors. There were no adverse events throughout the operation and blood loss was 70 mL. After the endotracheal tube was removed, he regained consciousness but presented left hemiplegia. On examination, his left limbs were weak with 2/5 muscle power and facial palsy on the left side. An urgent CT scan showed prior bilateral paraventricular infarction but no hematoma. Therefore, a provisional diagnosis of right-sided ischemic stroke was made. At 72 hours after surgery, infarction of the right basal ganglia emerged on a repeat CT scan (Fig. 3). After blood pressure management, intravenous fluids and aspirin treatment, the left limbs recovered from weakness and he was discharged to the rehabilitation department.

## Discussion

Carotid artery-related perioperative stroke following anterior cervical spine surgery is a rare but catastrophic cerebral vascular complication, which can result in severe neurologic consequences including weakness, hemi-paresis, and even death.[6-9] The incidence is extremely low and reported from 1/1000 to 1/17,625.[11,12] A review of literature using Medline and PubMed databases found that it is only detailed in 4 case reports. However, we reviewed records of 754 patients who underwent anterior cervical surgery from 2013 to 2017 at our institution, and 3 cases with carotid artery-related perioperative stroke were found. The incidence at our institution is 0.4%, which is likely higher than that suggested by cases reported in the literature. There were altogether 7 cases, as listed in Table 1. Perioperative stroke occurred more frequently in males (5 of 7 patients). The mean age of the patients was 62.3 years (ranging 41-80 years). Retraction time was at least 1 hour. Most patients had carotid artery atherosclerosis (5 of 7 patients) and 2 patients underwent transient hypotension during surgery.

Prolonged retraction of the common carotid artery, especially when the artery is atherosclerotic, is considered as the main cause of intraoperative ischemic stroke, and is further validated by our series.[6,7] In all of the 7 cases, retraction of the carotid artery and cerebral infarction were on the same side, with 5 of the 7 cases having had prior artery atherosclerosis and 2 patients were identified to have severe artery stenosis (Radhakrishnan et al[9] and Case 1). These results indicate that there is a significant correlation between prolonged carotid artery retraction, artery atherosclerosis, and perioperative stroke. Pollard et al[13] reported that intraoperative prolonged retraction of the common carotid artery could cause a 30%-67% decrease in the vessel cross-sectional area, which would lead to a decrease in the blood flow. The blood stasis may further cause thrombosis, especially at the site of atherosclerotic plaque or stenosis. When the duration of hypoperfusion is prolonged or the collateral compensation is inadequate, a stroke may occur. In addition, there is also the potential of unstable plaque displacement caused by retraction, though it has not been reported. Intraoperative


**Figure 3.** *Image from Case 3. Repeat computed tomography scan 72 hours after surgery showed newly emerged infarction of the right basal ganglia with prior bilateral paraventricular infarction.*

**Table 1.** *Summary of cases with carotid artery-related perioperative stroke following anterior cervical spine surgery*

| Study | Patient sex, age (year) | Treatment, approach | Retraction time (hour) | Carotid artery atherosclerosis | Intraoperative hypotension | Other previous history | Complications |
|---|---|---|---|---|---|---|---|
| Yeh et al | Male, 76 | C5-C6ACDF, left-sided | 5 | No | No | No | Large left hemisphere infarction, death |
| Chozick et al | Male, 74 | C3-C4ACDF, C4 C5ACCF, right-sided | 3 | Yes, right-sided | No | Diabetes | Right ICA thrombosis, right basal ganglia, corona radiata and frontal lobe infarction |
| Radhakrishnan et al | Male, 50 | C4-C6ACDF, right-sided | > 2 | Yes, right-sided | Yes | Hypertension | Right frontal lobe infarction |
| Loret et al | Female, 41 | C4-C6ADR, C6-C7ACDF, right-sided | 2 | No | No | Diabetes | Right ICA dissection, right ICA territory infarction |
| Case 1 | Male, 55 | C5-C7ACDF, right-sided | 1 | Yes, bilateral | No | Right MCA stenosis | Right MCA territory infarction |
| Case 2 | Female, 80 | C4-C6ACDF, right-sided | 1 | Yes, bilateral | Yes | Hypertension, diabetes, atrial fibrillation | Right corona radiata infarction |
| Case 3 | Male, 60 | C3-C4 C5-C7 ACDF, right-sided | 1.5 | Yes, bilateral | No | Diabetes, ischemic stroke | Right basal ganglia infarction |

ACCF, anterior cervical corpectomy and fusion; ACDF, anterior cervical discectomy and fusion; ADR, artificial disc replacement; ICA, internal carotid artery; MCA, middle cerebral artery.

adverse events, especially hypotension, would increase the occurrence of retraction-related ischemic stroke.[13] Radhakrishnan et al[9] reported a case of postoperative stroke following ACDF. The patient was on long-term antihypertensive medication and experienced hypotension intraoperatively, which is quite similar with the patient in Case 2. Intraoperative hypotension aggravated hypoperfusion, which was induced by retraction of the atherosclerotic vessel, can account for the stroke.

Preoperative identification of risk factors and adequate perioperative management can reduce morbidity and mortality. Risk factors of perioperative stroke include age greater than 65 years, history of stroke or transient ischemic attacks, atrial fibrillation, carotid atherosclerosis, male gender, and hypertension or hypotension.[9,14] Therefore, in order to prevent perioperative cerebral vascular accidents, a careful review of the patient's history, physical examination, and a thorough evaluation of the patient should be done prior to surgery. Our management protocols are provided in Table 2. For patients with significant risk factors, blood pressure, and diabetes should be well controlled. We recommend a routine carotid and transcranial Doppler ultrasound and possible CT angiography before surgery to detect the underlying pathology of the carotid and cerebral arteries.[6,7] The results could guide surgeons in making decisions of the surgical side. Apart from Doppler and CT angiography, cerebral perfusion imaging studies could be performed before surgery for patients with high risks of intraoperative stroke if available. Cerebral perfusion imaging studies, such as single photon emission CT, perfusion-weighted MRI, and CT perfusion, can allow for the determination of relative cerebral blood flow of patients. It is reported that patients with asymptomatic carotid artery disease and cerebral hypoperfusion are more likely to develop future strokes or transient ischemic attacks.[15,16] Therefore, for patients with evidently low relative cerebral blood flow, severe carotid artery stenosis, and inadequate compensation, the risks of intraoperative ischemic stroke are extremely high and a consultation with the neurovascular surgeon whether surgical intervention of artery stenosis is necessary should be obtained. Furthermore, intraoperative blood pressure management, especially for hypertensive patients, is of great importance in maintaining cerebral perfusion. Discussions should be made with an anesthesiologist before surgery regarding its necessity to avoid adverse events such as hypotension, hypoxia, or anemia at all cost. Intraoperative monitoring, such as transcranial Doppler ultrasound, cerebral oximetry, and electroencephalography, is beneficial but technically demanding, and could be arranged if resources permit.[7,17]

**Table 2.** *Summary of management protocols for carotid artery-related perioperative stroke following anterior cervical surgery*

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| Preoperation |
| • Careful history and physical examination and thorough evaluation. |
| • Identification of the risk factors. |
| • Optimization of control of hypertension, diabetes, etc. |
| • Carotid and transcranial Doppler and possible CT angiography to view circulation. |
| • Cerebral perfusion imaging study for patients with high risks. |
| • Consider operating from the side with better carotid perfusion. |
| • Discussion with anesthesiologist regarding need to avoid intraoperative adverse events. |
| • Arrange for intraoperative monitoring if resources permit. |
| • Assessment of perioperative antiplatelets therapy. |
| Intraoperation |
| • Use operating microscope and narrow lateral retractors to minimize lateral retraction. |
| • Blades under longus colli muscle. |
| • Intermittent retraction. |
| • Palpation of superficial temporal artery by anesthesiologist before and after retraction. |
| Postoperation |
| • Immediate head CT. |
| • Doppler, MRI, CT, or MRI angiography and conventional angiography if indicated. |
| • Immediate stroke team consultation. |
| • General supportive care and treatment, intravenous fluids, and aspirin. |
| • Endovascular interventions if indicated. |

CT, computed tomography; MRI, magnetic resonance imaging.

In the primary and secondary prevention of ischemic stroke, aspirin is most commonly used and plays a key role.[18] Aspirin can reduce the risks of thrombotic complications, but with the competing risks of bleeding or hemorrhage.[19] Therefore, the continuation of aspirin as prevention or prophylaxis for ischemic stroke is still debated among spinal surgeons. Some studies have demonstrated increased perioperative complications of bleeding, hemorrhage, and postoperative drainage when aspirin was continued in spine surgery,[20-22] while several other studies found that there were no increased risks in continuing low-dose aspirin in spine surgery. Once intraspinal hematoma occurs, however, it may lead to irreversible neurological deficits and increased morbidity.[23-25] Therefore, perioperative management of aspirin requires a case-by-case risk and benefit assessment. For patients with a low risk of perioperative cerebral infarction, our suggestion would be to interrupt aspirin use for 7-10 days, even though the use of aspirin is relatively safe if thorough hemostasis is achieved during surgery. The utility of preoperative platelet reactivity testing could be beneficial in assessing the risk of bleeding related to perioperative use of aspirin, and needs further investigation.

Intraoperatively, the use of an operating microscope and narrow lateral retractors to visualize only 1 level at a time would minimize the need for lateral retraction. The retractor blade should be placed under the longus colli muscle to minimize pressure on the carotid artery with a slight force and release intermittently if the operation is lengthy or hypotension develops. Palpation carried out by an anesthesiologist from the superficial temporal artery anterior to the ear before and after retraction to indirectly evaluate the blood flow of the carotid artery is admittedly crude but helpful.

Early recognition of symptoms postoperatively by the medical staff is critical if a stroke occurs. This requires a specific examination after recovery from general anesthesia and high vigilance of stroke-related symptoms. Once perioperative stroke is suspected, an emergency noncontrast head CT should be completed to discriminate ischemic stroke from hemorrhage, and a diffusion-weighted MRI which is sensitive to detect infarction could improve the diagnosis of ischemic stroke.[18] After diagnosis is made, a consultation with the "stroke team" managed by neurologists is highly recommended. Intra- and extracranial vascular imaging, such as CT angiography, MRI angiography, Doppler ultrasound, and conventional angiography, may help identify the mechanism of ischemia and make appropriate clinical decisions. General supportive care and treatment such as airway support, supplemental oxygen, temperature, and blood pressure management are also important, and hypovolemia should be corrected with intravenous fluids.[18] Intravenous thrombolysis is relatively contraindicated within 14 days of major surgery, but guidelines recommend that postoperative patients should be evaluated on a case-by-case basis and not be outrightly excluded from intravenous thrombolysis therapy.[18] Endovascular interventions, either alone or in combination with intravenous thrombolysis, is another option, which could increase the rate of recanalization at an acceptable level of safety.[8,26,27] Aspirin has been found beneficial in the treatment of acute ischemic stroke, and its use in the postoperative period was deemed safe.[25]

## Conclusions

Carotid artery-related perioperative stroke following anterior cervical spine surgery is extremely rare. Prolonged traction, carotid artery atherosclerosis, and intraoperative hypotension can produce cerebral hypoperfusion and cause ischemic stroke. In this study, we summarized the risk factors, and systematically and comprehensively proposed prevention and management protocols, which can be used to minimize the overall morbidity and mortality of this complication.

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