Malposition of the Selective Antegrade Cerebral Perfusion Catheter Identified by Carotid Ultrasonography: A Case Report

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ABSTRACT

Cerebral hypoperfusion can occur during aortic surgery. We present a case in which malposition of the selective antegrade cerebral perfusion (SACP) catheter was identified using carotid ultrasonography. A 66-year-old man underwent total arch replacement. SACP was initiated via the brachiocephalic artery following deep hypothermic circulatory arrest. However, right forehead regional oxygen saturation (rSO_2) remained unchanged. Carotid ultrasonography revealed no blood flow in the right common carotid artery, suggesting catheter malposition into the right subclavian artery. After a slight catheter withdrawal, blood flow was restored, and rSO_2 increased. Carotid ultrasonography, along with rSO_2 monitoring, is recommended for evaluating cerebral perfusion during SACP.

Keywords: Carotid ultrasonography, catheter malposition, selective antegrade cerebral perfusion

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INTRODUCTION

Selective antegrade cerebral perfusion (SACP) and deep hypothermic circulatory arrest (DHCA) are commonly used in aortic arch surgery to protect the brain from cerebral hypoperfusion. Timely detection and management of cerebral hypoperfusion can help mitigate the risk of preventable brain injury.[1] Malposition of the SACP catheter, placed in the brachiocephalic artery (BCA), has been reported in 11.4% of patients undergoing surgery for aortic arch aneurysms.[2] Herein, we report a rare case in which malposition of the SACP catheter was suspected based on carotid ultrasonography performed by the anesthesiologist at the level of the right carotid bifurcation, beneath the drape and outside the sterile field.

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CASE PRESENTATION

We obtained written informed consent from the patient for publication of this case report.

A 66-year-old man (height, 178 cm; weight, 67 kg) with a history of myocardial infarction presented with sudden chest pain. Contrast-enhanced computed tomography (CT) revealed an aortic dissection extending from the ascending aorta to both common iliac arteries. The aortic dissection extended from the origin of the BCA approximately 4 cm along its course, reaching to within about 1 cm of its bifurcation into the right subclavian artery (RSA) and the right common carotid artery (RCCA), without involving either branch. It also extended approximately 1.5 cm from the origin of the left common carotid artery (LCCA), while

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the left subclavian artery (LSA) was not involved. No abnormalities were noted on the head CT; however, due to the emergent nature of the surgery, the patency of the circle of Willis could not be assessed. Entry and reentry were not clearly identified on the CT, but the CT attenuation value of the false lumen suggested the possibility of an entry near the origin of the LSA. Given the anticipated deep surgical field of the distal arch, the patient was scheduled to undergo emergency total arch replacement with a frozen elephant trunk graft (J Graft Open Stent Graft®, Japan Lifeline Co., Ltd., Japan).

Upon arrival in the operating room, the blood pressure was 129/49 mmHg, and the heart rate was 79 bpm in sinus rhythm. The right radial artery was cannulated to monitor the arterial blood pressure. Regional oxygen saturation (rSO_2) was monitored bilaterally on the forehead using an INVOS™ 5100C system (Medtronic, USA). Before the induction of general anesthesia, the forehead rSO_2 values were 70% on the left side and 62% on the right side. General anesthesia was induced and maintained with remimazolam, fentanyl, ketamine, and rocuronium. A transesophageal echocardiography (TEE) probe was inserted, which revealed no regional wall motion abnormalities, mild aortic regurgitation, a small amount of pericardial effusion, and intact coronary arteries.

After performing a median sternotomy, an incision was made below the clavicle. To establish the perfusion route, a 9-mm inner diameter prosthetic graft (J Graft Straight®, Japan Lifeline Co., Ltd., Japan) was anastomosed to the LSA, just distal to the origin of the left vertebral artery. Arterial inflow for cardiopulmonary bypass (CPB) was initiated through this graft via the LSA. A venous cannula was inserted through the right femoral vein into the right atrium. After the initiation of CPB, the CPB pump flow was set at 2.4 L/min/m^2, and systemic cooling was performed. The forehead rSO_2 values were 78% on the left side and 80% on the right side when the urinary bladder temperature, measured using a precision urimeter (Becton, Dickinson and Company, USA), reached 25°C, at which point circulation was arrested to facilitate the aortic incision without the use of an aortic cross-clamp. The head-down position was adopted prior to DHCA to prevent air entry into the BCA and LCCA. Retrograde cardioplegia was administered through the retrograde coronary perfusion cannula that had been inserted before the initiation of DHCA, and it was subsequently repeated every 30 minutes. The heart was arrested using cold blood cardioplegia. Antegrade cardioplegia was not administered directly through the coronary ostia, as sufficient myocardial protection had already been achieved via retrograde delivery, and the planned duration of circulatory arrest was short. Following the initiation of DHCA, the LSA was ligated at its origin. Two minutes after DHCA onset, perfusion was initiated via the LSA perfusion route to provide cerebral perfusion through the left vertebral artery, as well as perfusion to the left upper limb. Subsequently, preparation for SACP via the LCCA and LSA was initiated. To facilitate the insertion of the SACP catheter into the arteries, the BCA was transected at a site unaffected by the dissection, approximately 1 cm proximal to its bifurcation, and the LCCA was similarly transected at a site unaffected by the dissection. Just before initiating SACP, the forehead rSO_2 value decreased to 50% on the left side and 60% on the right side [Figure 1]. During SACP, the perfusion pressure was monitored at both the right radial artery and the tip of the SACP catheter. Thirteen minutes after DHCA onset, the initial attempt at BCA perfusion was undertaken. SACP was initiated via the BCA, with the pressure at the catheter tip measured at 58 mmHg, equivalent to the right radial artery pressure [Figure 1]. Under typical circumstances, such a finding would indicate adequate perfusion of the right cerebral hemisphere. However, no concomitant increase in right forehead rSO_2 was observed. This discrepancy was considered atypical and prompted further evaluation. The position of the SACP catheter was adjusted, but since there was still no change in rSO_2, preparations for cannulation of the LCCA were initiated according to the plan. Carotid ultrasonography performed by an anesthesiologist at the level of the right carotid bifurcation, beneath the drape and outside the sterile field, revealed no detectable blood

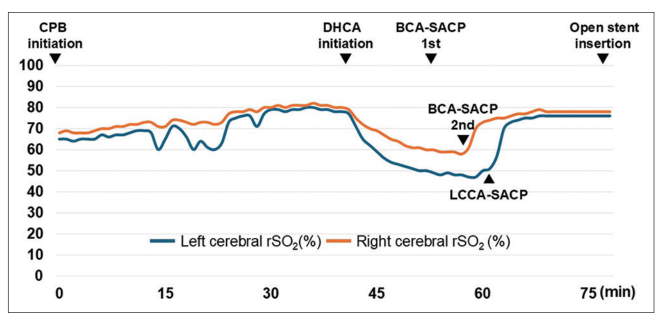


Figure 1: Cerebral regional oxygen saturation during cardiopulmonary bypass. Bilateral cerebral regional oxygen saturation (rSO_2) began to decrease following the initiation of deep hypothermic circulatory arrest (DHCA), which was commenced approximately 41 minutes after the initiation of cardiopulmonary bypass (CPB). Selective antegrade cerebral perfusion (SACP) was initiated through the brachiocephalic artery (BCA) at 54 min; however, no changes were observed in the right cerebral rSO_2 (BCA-SACP 1st). The catheter was slightly withdrawn at 58 min, after which the right cerebral rSO_2 subsequently increased (BCA-SACP 2nd). SACP was initiated via the left common carotid artery (LCCA) at 54 min, after which the left cerebral rSO_2 subsequently increased (LCCA-SACP)

flow in the RCCA [Figure 2a]. Despite the elevated right radial artery pressure, the absence of blood flow in the RCCA suggested that the SACP catheter may have advanced too far into the BCA and potentially entered the RSA. The catheter was slightly withdrawn, after which carotid ultrasonography confirmed blood flow in the RCCA [Figure 2b]. After repositioning, correct BCA perfusion was established four minutes later. The right forehead rSO_2 subsequently increased to 78% [Figure 1]. When SCP was initiated through the LCCA, blood flow in the LCCA was confirmed with carotid ultrasonography and the left forehead rSO_2 increased to 76% [Figure 1]. After transecting the aortic arch, the surgeon confirmed the placement of a frozen elephant trunk graft into the true lumen by visualizing it from the distal aorta, with correct positioning further confirmed by TEE during insertion. A four-branch prosthetic graft (J Graft 4 Branched Spiral ®, Japan Lifeline Co., Ltd., Japan) was attached distally. After clamping the most proximal portion of the graft, blood flow to the lower body was initiated via the most proximal branch of the graft. The proximal anastomosis was performed, followed by the release of the aortic cross-clamp. Reconstruction was performed in sequence, first of the LCCA and then of the BCA. Finally, the prosthetic graft anastomosed to the LSA was tunneled subcutaneously and connected to the four-branch prosthetic graft. Extracorporeal circulation was then discontinued. The duration of the operation, CPB, and BCA SACP were 438, 243, and 131 min, respectively. The patient was transferred to the intensive care unit postoperatively while intubated. He was extubated on postoperative day 1. The postoperative course was uneventful, and no complications were observed.

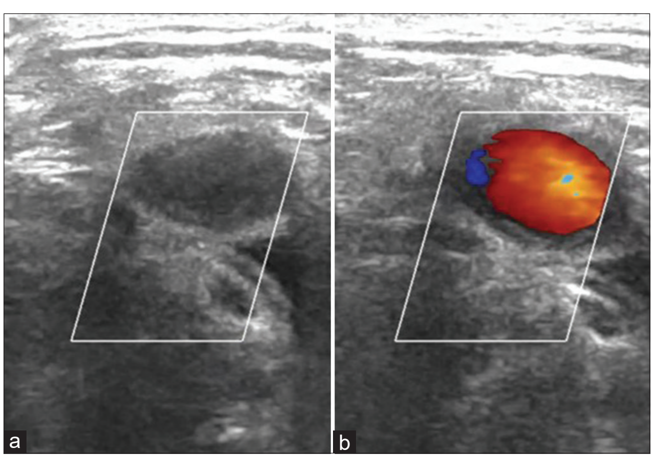


Figure 2: Intraoperative carotid Doppler ultrasonography. After initiation of selective antegrade cerebral perfusion via the brachiocephalic artery, carotid ultrasonography of the right common carotid artery revealed no detectable blood flow (a). Upon slight withdrawal of the catheter, blood flow in the common carotid artery was observed (b)

DISCUSSION

We identified two critical issues related to malposition of the SACP catheter. First, an increase in rSO_2 should be confirmed each time SACP is initiated to avoid cerebral hypoperfusion caused by SACP catheter malposition. Second, diagnosing cerebral hypoperfusion during SACP can be challenging when relying solely on perfusion pressure and rSO_2 measurements but incorporating carotid ultrasonography improves the diagnostic reliability.

Near-infrared spectroscopy oxygenation (NIRS) is a useful, noninvasive monitoring method for detecting cerebral hypoperfusion in patients undergoing aortic arch surgery.[1] Therapeutic interventions are often applied in response to a decrease in rSO_2.[1] The right forehead rSO_2 was 80% before DHCA and decreased to 60% after DHCA, corresponding to 75% of the baseline value. Neurological complications have been reported to be closely associated with a relative decrease in rSO_2 to 65%–80% of baseline[3] or with the duration of time in which rSO_2 drops below 60%,[4] suggesting the need for therapeutic intervention. As with the SACP to the LCCA in the current case, the initiation of SACP is generally expected to result in an increase in rSO_2.[5] In this case, after the initiation of SACP, perfusion pressure was observed; however, even after adjusting the position of the SACP catheter, no increase in right forehead rSO_2 was noted. The circle of Willis was not evaluated; however, even if perfusion via the BCA is inadequate, a decrease in rSO_2 may be masked by compensatory LCCA perfusion through the circle of Willis, potentially delaying the detection of catheter malposition. Therefore, rather than evaluating cerebral perfusion only after initiating all SCP catheters, it is important to evaluate it each time a single SCP catheter is started. Additionally, it is crucial to determine whether rSO_2 increases after SACP initiation and to confirm adequate flow using carotid ultrasonography.

Hypoperfusion of the right vertebral artery may occur when a SACP catheter migrates into the RCCA, which can be detected through perfusion pressure measurements at the right radial artery. In contrast, migration into the RSA can cause hypoperfusion of the RCCA, detectable using NIRS [Figure 3]. In cases like this, where the BCA is trimmed shorter due to dissection, it is important to closely monitor cerebral perfusion. Methods for early detection of cerebral hypoperfusion have been reported through continuous monitoring, such as NIRS and perfusion pressure, followed by evaluation with orbital ultrasonography and TEE.[2] Orbital ultrasonography is useful for evaluating cerebral hypoperfusion during SACP; however, prolonged imaging or high output energy may cause thermal damage to the ocular

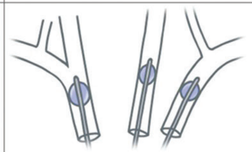
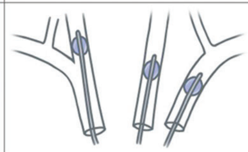
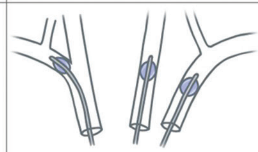
	Correct position	RCCA cannulation	RSA cannulation
Figure			
Right radial artery pressure	≒ BCA inflow pressure	Not perfused	≒ BCA inflow pressure
RCCA perfusion	Perfused	Perfused	Not perfused
RVA perfusion	Perfused	Not perfused	Perfused

Figure 3: Malposition of the selective antegrade cerebral perfusion catheter in the brachiocephalic artery. When correctly positioned in the brachiocephalic artery (BCA), a selective antegrade cerebral perfusion catheter ensures perfusion to both the right common carotid artery (RCCA) and the right subclavian artery (RSA). However, inadvertent advancement of the catheter tip into either the RCCA or RSA may compromise cerebral perfusion through the RCCA or the right vertebral artery (RVA)

tissues.[6] TEE can visualize the tip of the catheter inserted into the BCA, allowing for identification of the cause,[2] but visualizing the BCA is generally difficult due to blind spots.[7] Carotid ultrasonography is effective for detecting cerebral hypoperfusion because carotid ultrasonography allows for easy evaluation of the bilateral common carotid and vertebral arteries, especially during SACP. Carotid ultrasonography also complements monitoring of perfusion pressure and rSO_2 during aortic arch surgery.

CONCLUSION

It is recommended to use carotid ultrasonography in addition to NIRS and perfusion pressure monitoring when evaluating cerebral perfusion during CPB.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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