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CASE REPORTS / CASE SERIES

Cannula malposition during antegrade cerebral perfusion for aortic surgery: role of cerebral oximetry

Mauvais positionnement de canule lors de perfusion cérébrale antérograde pour chirurgie aortique: rôle de l'oxymétrie cérébrale

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Abstract

Purpose *To describe the use of cerebral oximetry to detect a lack of right cerebral perfusion resulting from a malpositioned catheter used for antegrade cerebral perfusion during deep hypothermic circulatory arrest (DHCA). The simple corrective surgical adjustment that followed averted a potentially serious complication.*

Clinical features *A 57-yr-old male with a type-A aortic dissection undergoing DHCA required antegrade cerebral perfusion for cerebral protection. Catheters were placed accordingly in the left common carotid and brachiocephalic arteries. Whereas frontal cerebral oximetry immediately improved on the left, it did not improve on the right. It was immediately suspected that the tip of the brachiocephalic cannula had advanced into the right subclavian artery, thus depriving the right common carotid artery of blood flow. The problem resolved upon slight withdrawal of the cannula.*

Conclusion *Vigilance in anesthesia should not stop during DHCA or cardiopulmonary bypass. Cerebral oximetry may provide important information leading to actions that improve brain protection. Vigilances proved important in this case where the cannula tip used for antegrade cerebral perfusion was advanced too far into the right subclavian artery.*

Résumé

Objectif *Décrire l'utilisation de l'oxymétrie cérébrale dans la détection d'un défaut de perfusion cérébrale à droite suite à un mauvais positionnement d'un cathéter de perfusion cérébrale antérograde pour un arrêt circulatoire avec hypothermie profonde (DHCA). Le simple ajustement chirurgical qui a suivi pour corriger la situation a évité une complication potentiellement grave.*

Caractéristiques cliniques *Un patient, âgé de 57 ans, porteur d'une dissection aortique de type A nécessitant une DHCA, a reçu une perfusion cérébrale antérograde sélective pour la protection de son cerveau. Des cathéters ont donc été mis en place dans la carotide*

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primitive gauche et dans le tronc brachiocéphalique. Alors que l'oxymétrie cérébrale frontale était immédiatement améliorée du côté gauche, elle ne s'est pas améliorée du côté droit. On a immédiatement soupçonné que l'extrémité de la canule brachiocéphalique avait avancé vers l'artère sous-clavière droite, privant ainsi l'artère carotide primitive droite de débit sanguin. Le problème a été résolu en tirant légèrement sur la canule.

Conclusion *La vigilance au cours de l'anesthésie ne doit pas cesser au cours de la DHCA ou de la circulation extracorporelle. L'oxymétrie cérébrale peut fournir une information importante débouchant sur des actions qui améliorent la protection cérébrale. La vigilance s'est avérée importante dans ce cas où l'extrémité de la canule utilisée pour la perfusion cérébrale antérograde était trop avancée dans l'artère sous-clavière droite.*

Circulatory arrest to ensure a bloodless and motionless surgical field is required during repair or replacement of the distal ascending aorta or aortic arch. The strategies for brain protection during this critical period when blood flow to the brain is absent include moderate to deep hypothermic circulatory arrest (DHCA) using cardiopulmonary bypass (CPB)[1] and use of drugs to reduce the cerebral bispectal index (BIS) to zero.[2] At 18-24°C and with much of the patient's upper head packed in ice, the incidence of serious postoperative permanent brain dysfunction is low if circulatory arrest is < 30 min.[3,4] Use of antegrade cerebral perfusion (Fig. 1) may allow for longer durations of circulatory arrest, allow a milder degree of hypothermia, obviate the need for circulatory arrest, and reduce the incidence and severity of postoperative brain dysfunction.[3-5] An alternative is retrograde cerebral perfusion via the superior vena cava or even integrated antegrade and retrograde cerebral perfusion.[3] Neither cerebral perfusion technique is clearly superior and the choice depends on surgical preference and circumstances.[3]

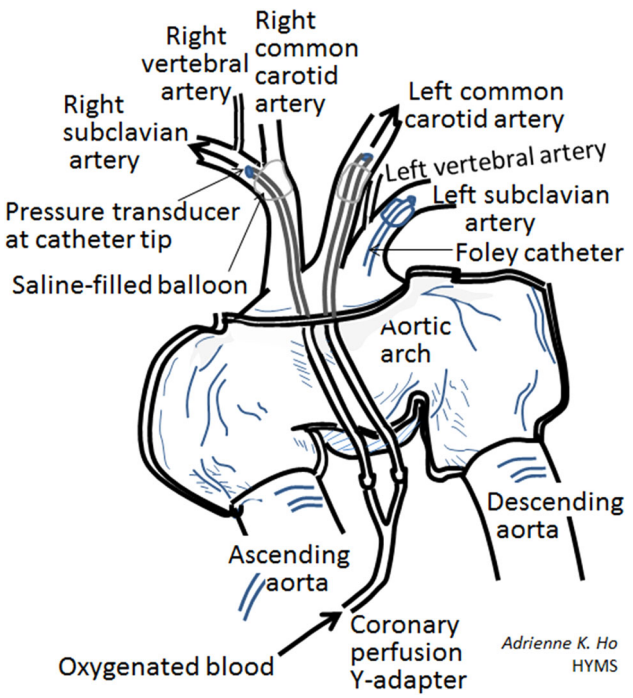

Fig. 1 A malpositioned catheter used in antegrade cerebral perfusion resulted in non-perfusion of the right common carotid artery (adapted from http://www.mac-conference.com/xconfig/upload/files/Vascutek%20_3%20Thoraflex%20Hybrid_Shrestha%281%29.pdf [accessed October 25, 2013])

Regional cerebral oxygen saturation (rSO_2) monitoring has emerged as an important technique for surgery involving the distal ascending aorta and aortic arch.[6] We herein report a case in which use of rSO_2 not only signalled the need to provide cerebral perfusion after a period of circulatory arrest, but also allowed the immediate detection of a malpositioned cannula used for antegrade cerebral protection that failed to perfuse the right common carotid artery as intended.

Case report

The patient gave signed consent for publication of this report.

A 57-yr-old, 90-kg, 166-cm male was diagnosed with a chronic type-A aortic dissecting aneurysm (measuring 4.8 cm at the ascending aorta) involving the brachiocephalic trunk, left common carotid artery, and left subclavian artery. The patient underwent aortic arch repair with CPB using femoral artery and double-stage inferior vena cava cannulae, a left ventricular vent via the right superior pulmonary vein, and DHCA. Intraoperative monitors included bilateral radial arterial cannulae, a right internal jugular central venous cannula, bilateral frontal rSO_2 (INVOS^{TM}, Covidien, Troy, MI, USA), BIS, plus the routine monitors[7] for major cardiac surgery.

Induction of anesthesia was uneventful. Ice was packed around the patient's head soon after CPB was started. Deep hypothermic cardiac arrest was carried out by cooling the patient to 18°C rectally. Thiopentone 500 mg was given prior to stopping the CPB pump,[2] immediately achieving a BIS reading of 0. A timer was started at the onset of DHCA, whereupon the aorta was divided and cold blood cardioplegia was administered. Surgical repair started with the aortic arch divided between the innominate artery and just distal to the left subclavian artery.

After almost 30 min of DHCA and aortic repair, bilateral rSO_2 fell 20% below baseline and completion of the operation

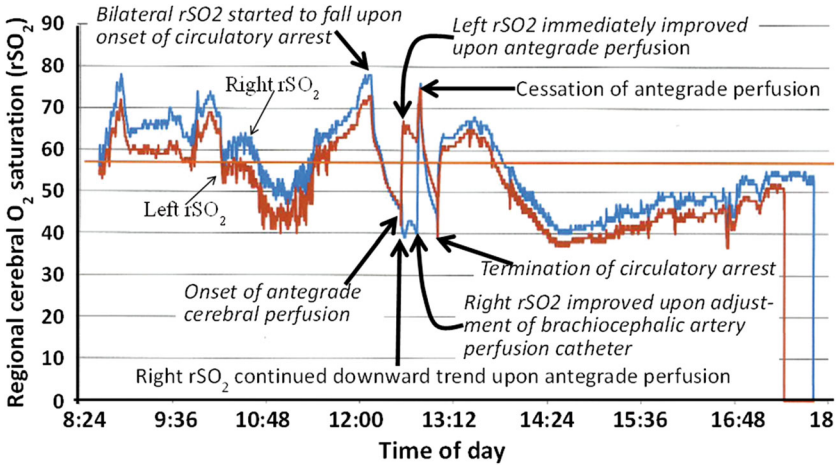

Fig. 2 Timeline of bilateral cerebral oximetry (rSO_2) monitoring. Baseline rSO_2 was 57% before induction of anesthesia (horizontal blue line with red line superimposed). Bilateral rSO_2 dropped below baseline upon the first initiation of cardiopulmonary bypass (CPB; before cross-clamping the ascending aorta with retrograde perfusion via femoral and right atrial lines) at around 10:40 when systemic blood pressure dipped and lung ventilation stopped with inflow of venous admixture via the heart. The rSO_2 improved when the ascending aorta was cross-clamped at about 11:20. Bilateral rSO_2 also dropped below baseline upon re-initiation of CPB after circulatory arrest at 13:50, possibly due to rewarming of the brain and hypotension, as requested by surgeons in view of bleeding

was not imminent. Antegrade cerebral perfusion was started using two 14-Fr cannulae with saline-filled balloon tips (Fig. 1) with an independent roller pump to maintain an oxygenated blood flow of 10-12 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ (maximum 1,200 $mL{\cdot}min^{-1}$) and balloon tip pressure of 30-40 mmHg.[5] The left subclavian artery was occluded with a 10-Fr Foley catheter to prevent a "steal" caused by blood flowing into the arm via the left vertebral artery. The left rSO_2 quickly recovered but, unexpectedly, the right rSO_2 did not (Fig. 2). The right radial blood pressure increased from ~20 mmHg to ~90-100 mmHg while the left radial pressure stayed at ~20 mmHg. The unresponsive right rSO_2 plus the excessive increase in right radial pressure suggested that the tip of the right catheter used for cerebral perfusion might have been placed within the right subclavian artery (Fig. 1). The surgeons pulled back the catheter slightly and the rSO_2 quickly recovered (Fig. 2).

Total circulatory arrest time was 76 min. Surgery and anesthesia were otherwise completed uneventfully. The postoperative course was complicated by difficulties weaning the patient from the ventilator. The patient's trachea was extubated four days after surgery, and he was transferred the following day to a high-dependency unit where he stayed for one day. He was discharged home two weeks later. Postoperatively, the patient did not have any gross neurologic deficit, delirium, or seizures.

Discussion

In this patient, the combination of a drop in rSO_2 in the right frontal lobe and normal rSO_2 in the left frontal lobe was a crucial event pointing to malpositioning of the catheter used in right antegrade cerebral perfusion. Other monitoring parameters of concern were the unusually high pressure at the catheter tip (Fig. 1), suggesting it may be abutting a vessel wall, and the higher than expected right radial pressure due to unexpectedly high flow. Since the BIS reading was already at 0, it would not have been able to detect any unilateral perfusion deficit. If the problem had not been detected (which would have been the case if cerebral oximetry had not been used or if the anesthesiologists had not noticed the non-recovering rSO_2 tracing), perfusion of the right brain would likely have been compromised during prolonged DHCA. The unilateral failure of the rSO_2 to recover suggested that the poor rSO_2 was not the result of skin ischemia or vasopressors.[8,9]

At our institution, we routinely place bilateral radial arterial monitors in patients undergoing aortic arch surgery. Even without rSO_2, it is conceivable that the high right radial pressure alone would have alerted the team to a malpositioned cannula. Nevertheless, the reliability of using the right radial arterial pressure alone in detecting such malpositioning is unknown. We prefer to cannulate the innominate artery rather than the right common carotid artery for several reasons: it is more difficult to cannulate the deeper carotid artery; vessels closer to the cranium are more fragile and harder to repair if a tear should occur; cannulation of the innominate artery allows perfusion of the right vertebral artery and right arm. An unexpected low right radial pressure would result if the right common carotid artery was inadvertently cannulated.[10]

Malpositioning of the catheter used in antegrade cerebral perfusion is not rare. In 35 consecutive patients

with aortic arch aneurysm undergoing total arch replacement or transaortic stent graft implantation, a drop in rSO_2 led to the detection of four cases requiring the antegrade perfusion catheter to be withdrawn slightly (as in our case) or replaced.[10] Not surprisingly, rSO_2 failed to detect an accidental entry of the catheter into the right common carotid artery, which was detected by transesophageal echocardiography.[10]

Unilateral cerebral desaturation during aortic arch surgery that is unrelated to catheter malpositioning during antegrade perfusion can also occur. Agostini *et al.*[11] described a case of type-A aortic dissection repair. Cardiopulmonary bypass was performed with a right axillary artery side graft for arterial inflow. An abrupt drop in the right rSO_2 to 15% occurred upon initiation of CPB, while the left rSO_2 decreased to 40-50%. An expansion of the false aortic lumen along the right epiaortic vessels was suspected. To improve perfusion through the true lumen, a second side graft was then added to increase arterial inflow for CPB. Bilateral rSO_2 gradually returned to baseline. The patient was discharged 12 days postoperatively without apparent neurologic deficit. Janelle *et al.*[12] reported a case of ruptured DeBakey type-1 aortic dissection. During aortic valve replacement, an abrupt profound drop in right rSO_2 was observed, which led to immediate temporary suspension of the valve replacement and immediate initiation of circulatory arrest. A false lumen was found extending from the ascending aorta through the right innominate artery into the right common carotid artery. The arch was repaired under retrograde cerebral perfusion, during which no improvement in right rSO_2 was observed while the left rSO_2 continued to decrease. Bilateral rSO_2 improved after the arch repair and re-institution of antegrade CPB via cannulation of the ascending aortic graft. Wang *et al.*[13] found a sudden drop in rSO_2 from 51% to 34% while the sternum was being rewired after total arch replacement with the elephant trunk technique. Immediate reopening of the sternum led to the discovery of colour change in the innominate artery distal to the anastomosis of the aorto-innominate vascular graft, suggesting acute dissection likely due to clamp injury. Immediate repair was carried out and the patient recovered.

Incompleteness of the Circle of Willis due to missing anterior (22%) or left posterior (46%) communicating arteries occurs in 20-30% of the population,[14] which might explain why, in our case and in the cases[10-13] cited above, flow from the left cerebral circulation was insufficient in perfusing the right side. In some of our other cases, perfusion of the left common carotid artery alone led to improvement in both left and right rSO_2, thus increasing bilateral brain protection with only left common carotid perfusion (for better exposure) while arch repair was underway. In a series of 13 cases with bilateral rSO_2 monitoring, Harrer *et al.*[15] found that 12 patients required bilateral antegrade cerebral perfusion instead of just left common carotid artery antegrade cerebral perfusion. A systematic review of the literature led Zheng *et al.*[16] to conclude that reductions in rSO_2 during cardiac surgery may provide an indication of mechanical mishaps related to CPB cannulae, particularly during aortic surgery.

To calculate rSO_2, cerebral oximetry transcutaneously measures differences in pulsed near-infrared light absorption between oxygenated and deoxygenated hemoglobin in the frontal lobes of the cerebral cortex.[16] The probes are optimally placed on both sides of the patient's forehead cephalad enough not to overlie the frontal sinuses. The regional saturation index, derived from venous blood (70-75%) and arterial blood (25-30%), reflects oxygen consumption and delivery, respectively. Cerebral oximetry is often considered a "first alert" monitor for reduced cerebral perfusion due to shock, interruption of carotid supply, hyperventilation, and poor blood oxygenation. A drop in the rSO_2 indicates decreased arterial oxygen supply and/or increased oxygen extraction, suggesting increased ischemic risk. Unlike pulse oximetry, cerebral oximetry does not require blood pulsatility.

Using a decrease in cerebral oximetry of $> 25\%$ from baseline as an indicator of increased ischemic risk, Murkin *et al.*[17,18] made corrective measures that included augmentation of oxygen delivery and reduction in brain oxygen consumption (e.g., increased blood pressure; blood transfusion; adjustments in ventilation, head and neck position, acid-base, and temperature; and increased depth of anesthesia) and achieved reduced major organ morbidity and length of hospital stay in monitored patients undergoing cardiac surgery.[17,18] Deschamps *et al.*[19] found rSO_2 desaturation occurring in 49% of the patients in high-risk or complex cardiac surgery. This was reversed by repositioning the patient's head, and optimization of oxygen delivery to the brain was achieved in 88.2% of cases. Fischer *et al.*[6] found that patients whose rSO_2 was under the absolute threshold of 60% for more than 30 min while undergoing aortic arch repair had an extended hospital stay of four days. In a patient with Raynaud's phenomenon, a bilateral drop in rSO_2 with concomitant loss of finger pulse oximetry was reversed with intravenous nitroglycerin after separation from CPB.[20]

Likewise, other authors have shown that optimization of rSO_2 may help prevent hypoxic brain injury and reduce length of hospital stay in higher risk patients undergoing major abdominal surgery.[21] Reduction in rSO_2 also predicts postoperative cognitive dysfunction in thoracic surgery[22] and is a reliable indicator of clamping ischemia in carotid endarterectomy.[23]

In conclusion, we have presented a case to remind anesthesiologists that vigilance should not stop during

DHCA or cardiopulmonary bypass. In fact, cerebral desaturation is common, with a reported incidence of up to 50% during CPB.[19] In our case, bilateral cerebral oximetry indicated a decrease in cerebral perfusion as rSO_2 had fallen 20% below baseline 30 min after initiation of circulatory arrest. It also alerted the team that a cannula tip for antegrade cerebral perfusion had been misplaced too far into the right subclavian artery. Further studies are required for a more precise calculation of the benefits and cost-effectiveness of routine cerebral oximetry in type-A aortic dissection surgery.

Conflicts of interest None declared.

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