

Cerebral oxygenation monitoring in patients with bilateral carotid stenosis undergoing urgent cardiac surgery: Observational case series

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ABSTRACT

Background: Patients with significant bilateral carotid artery stenosis requiring urgent cardiac surgery have an increased risk of stroke and death. The optimal management strategy remains inconclusive, and the available evidence does not support the superiority of one strategy over another. **Materials and Methods:** A number of noninvasive strategies have been developed for minimizing perioperative stroke including continuous real-time monitoring of cerebral oxygenation with near-infrared spectroscopy (NIRS). The number of patients presenting with this combination (bilateral significant carotid stenosis requiring urgent cardiac surgery) in any single institution will be small and hence there is a lack of large randomized studies. **Results:** This case series describes our early experience with NIRS in a select group of patients with significant bilateral carotid stenosis undergoing urgent cardiac surgery ($n = 8$). In contrast to other studies, this series is a single surgeon, single center study, where the entire surgery (both distal ends and proximal ends) was performed during single aortic clamp technique, which effectively removes several confounding variables. NIRS monitoring led to the early recognition of decreased cerebral oxygenation, and corrective steps (increased cardiopulmonary bypass flow, increased pCO_2 , etc.) were taken. **Conclusion:** The study shows good clinical outcome with the use of NIRS. This is our “work in progress,” and we aim to conduct a larger study.

Key words: Bilateral carotid stenosis; Near-infrared spectroscopy; Stroke; Urgent cardiac surgery

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INTRODUCTION

Patients with significant bilateral carotid artery stenosis (CAS) requiring urgent cardiac surgery have increased the risk of stroke, mortality, and morbidity.^[1] The etiology of adverse outcomes is multifactorial and incompletely understood. EuroSCORE regards carotid stenosis >50% as a risk factor.^[1,2] Patients presenting with this combination (concomitant cardiac and severe bilateral CAS) are small in number, and optimal management strategy remains inconclusive.^[3,4] There is a need for improved cerebral surveillance, and several noninvasive strategies have been developed including continuous real-time monitoring of cerebral oxygenation with near-infrared spectroscopy (NIRS).^[5]

We present our early experience with NIRS in a select group of patients with bilateral CAS undergoing urgent cardiac surgery. All patients were operated by a single surgeon who used

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standard technique of anesthesia, cardiopulmonary bypass (CPB), myocardial protection, and surgical technique. In contrast to the previous studies, this series is single surgeon, single center study where entire surgery (both distal ends and proximal ends) was performed using single aortic clamp technique. It effectively removes confounding effect of different surgeons with wide variations in practice during the perioperative period which can have effect on cerebral oximetry results.

PATIENTS AND METHODS

It was prospective observational series including eight patients who underwent urgent cardiac surgery with bilateral CAS at Heart and Lung Centre, Wolverhampton, United Kingdom. Seven patients were referred for urgent coronary artery bypass grafting (CABG) due to acute coronary syndrome. One patient underwent aortic valve replacement following in-hospital transfer as he was decompensating. Audible carotid bruit prompted carotid Doppler. The patients with more than 50% carotid stenosis on both sides plus combined stenosis of more than 120% were included. Carotid duplex scanning and computerized tomographic (CT) angiography of the circle of Willis were performed. Vascular surgeon's opinion was to target the more symptomatic territory first, i.e., to perform the cardiac surgery first. Baseline demographic and clinical characteristics are summarized in Table 1.

Intraoperative monitoring included an electrocardiogram, radial arterial catheter, and bifrontal Equanox™ (Nonin Medical Inc., Minnesota, MN) cerebral oximetry system to measure cerebral oxygen saturation (rSO₂). Preoperative baseline rSO₂ was established without supplemental oxygen (pre-CPB). Further measurements were taken during CPB (on CPB) and postoperatively (post-CPB). The anesthetic technique included target controlled

total intravenous anesthesia using propofol and remifentanyl with rocuronium as a muscle relaxant. Intravenous morphine bolus was administered at end of the procedure and continued as infusion for postoperative analgesia.

All patients were operated by a single surgeon. Surgery was performed via median sternotomy, and CPB was established with the cannulation of ascending aorta and right atrium. The cardioplegic arrest was achieved with cold blood cardioplegia, and CPB was performed at a temperature of 32–34°C. Routine management of mean arterial pressure (MAP) during CPB at our institution is 50–55 mmHg. A higher MAP of 60–65 mmHg on CPB was chosen due to known bilateral CAS. The surgeon used single aortic clamp technique during CABG for distal and proximal anastomoses, which is routine in his practice.

If rSO₂ on CPB fell to <10% under baseline, pressure on CPB was increased to maintain baseline rSO₂. Despite these interventions, in one case inability to maintain rSO₂ above this threshold was observed. Three patients showed a decrease of rSO₂ on CPB, which necessitated increase of MAP >70 mmHg. Two patients responded with increase of rSO₂ to preoperative values. However, one patient did not respond and required increase of PCO₂ to 6 kPa to restore preoperative rSO₂ [Table 2]. Cerebral rSO₂ was not monitored postoperatively.

Mean length of hospital stay was 9.8 days. Postoperatively, four patients had no complications, and three patients developed postoperative atrial fibrillation (AF). Patient number 2 reported reduced left arm movement on day 2 postoperative lasting around 48 h. This developed soon after she went into AF. CT brain confirmed an embolic event of the right hemisphere. She also experienced postoperative acute renal failure needing hemofiltration. Subsequent clinical recovery was slow and at 6 months

Table 1: Baseline demographic and clinical characteristics

Pt No	Sex	Age	CVA	RICA (%)	LICA (%)	Log Euro	Procedure	CPB	X clamp
1	F	63	No	90	90	5.2	CABG	107	91
2	F	72	No	90	70	20.79	CABG	110	87
3	M	81	Yes	80	70	22.84	AVR	100	86
4	M	73	No	70	60	9.78	CABG	97	81
5	M	79	No	70	80	9.61	CABG	95	84
6	M	67	No	70	100	8.16	CABG	105	94
7	M	72	No	70	50	3.91	CABG	112	90
8	M	65	Yes	60	95	6.41	CABG	80	63

Pt No: Patient number, CVA: Cerebrovascular accident, RICA: Right Internal carotid artery stenosis, LICA: Left internal carotid artery stenosis, Log Euro: Logistic euroscore, CPB: Cardiopulmonary bypass time, X Clamp: Cross clamp time

Table 2: Perioperative changes in right and left regional oxygen saturation (rSO₂) signals

Patient	Right rSO ₂ (%)			Left rSO ₂ (%)			MAP (mmHg)
	Pre CPB (on air)	On CPB	Post CPB	Pre CPB (on air)	On CPB	Post CPB	
1	73	69	74	72	68	73	>60
2*^	76	65	72	71	68	80	>70
3	75	65	74	74	68	75	>60
4	80	71	79	78	70	78	>60
5	68	67	73	72	68	72	>60
6*	71	65	70	70	64	68	>70
7	68	64	68	70	68	69	>60
8*	70	68	70	68	64	67	>70

A preoperative baseline cerebral oxygen saturation was established without supplemental oxygen (pre CPB). Further measurements were taken during cardiopulmonary bypass (on CPB). All patients were monitored for first 24 hours postoperatively and lowest saturation recorded was noted (post CPB). The recorded rSpO₂ were the lowest recorded during the interval (either during CPB or after CPB). There were changes in the right and left rSO₂ signals during CPB. *Three patients required an increase of MAP on CPB which led to gradual improvement. **Patient number 2 did not respond to a higher perfusion pressure. An increase of systemic pCO₂ to 6 kPa led to gradual recovery. MAP: Mean arterial pressure, pCO₂: Partial pressure of carbon dioxide

follow-up, the patient was fully rehabilitated with no residual upper limb paresis.

DISCUSSION

Patients with bilateral CAS requiring urgent cardiac surgery have increased risk of stroke and death.^[4,5] The optimal management of such patients remains controversial.^[1,2] Gold *et al.*, showed that the use of high MAP during CPB reduces the overall incidence of combined cardiac and neurological complications.^[3] Johnsson *et al.*, showed no increased incidence of perioperative neurologic events using an MAP >70 mmHg during CPB in patients with significant bilateral CAS.^[2] Their findings are in agreement with observations of our case series showing no neurological event with MAP on CPB of more than 60 mmHg. One patient, however, suffered TIA, but this was probably related to postoperative AF.

Maintaining cerebral rSO₂ in preoperative range reduces incidence of postoperative cognitive dysfunction and general morbidity.^[3,4] NIRS allows assessment of cerebral oxygen delivery and demands ratio to the frontal cortex.^[5] Routine use of cerebral rSO₂ monitoring during cardiac surgery may improve patient outcome and shorten hospital stay.^[3-5] Cerebral monitoring using NIRS can identify otherwise unrecognized cerebral hypoperfusion during aortic surgery as well.^[3-5]

Three patients in this case series demonstrated a decrease of rSO₂ on CPB, which necessitated increase of MAP on CPB from 60 to 70 mmHg. One patient responded with an increase of rSO₂ to normal values.

However, the other patient showed no improvement of rSO₂ and an increase of PCO₂ was necessary. This caused cerebral arterial vasodilation and improvement of rSO₂. Additional interventions may include the patient's head position and increasing of cardiac index/pump flow or blood transfusions.^[6]

Embolic infarction in nonmonitored sites may occur without NIRS signal change, and thus a maintained signal is not always an assurance of cerebral well-being.^[3-5,7] Electrocautery may interfere with NIRS monitoring.^[3-5] NIRS cannot differentiate the cause of rSO₂ change, e.g., severe anemia.^[4] In our series, arterial oxygen saturation and hemoglobin levels were maintained around the preinduction baseline. NIRS monitoring can provide a warning that cerebral ischemia is likely to be present at a given point of time, and corrective measures should be taken.

NIRS has been extensively used in patients undergoing cardiac surgery to find an association between the measurements of cerebral oxygenation and postoperative outcome.^[8-10] Several studies have found an association between intraoperative cerebral oxygen desaturation and postoperative cognitive dysfunction, stroke, and prolonged hospital stay.^[10,11]

There is no evidence base for the management of patients with severe bilateral CAS, who require urgent cardiac surgery. Our approach to these patients was a joint decision of the multidisciplinary team (vascular surgeons, cardiac surgeons, and anesthetists). As every center deals with small number of such patients, only a large multicenter international randomized study

can provide evidence base for the management of these patients.

CONCLUSION

Urgent cardiac surgery in patients with significant bilateral CAS requires careful intraoperative monitoring and adjustment of perioperative technique. NIRS is helpful adjunct in such patients to ensure adequate cerebral perfusion. Large randomized studies are required to further clarifying the role of NIRS in this setting. This is our “work in progress,” and we aim to conduct a larger study.

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Conflicts of interest

There are no conflicts of interest.

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