ISSN: 1607-8322, e-ISSN: 2220-5799 **Anaesthesia, Pain & Intensive Care**
Vol 27(6); December 2023 DOI: 10.35975/apic.v27i6.2350

CASE SERIES **ANESTHESIA & CONCURRENT DISEASE**

How NIRS can predict the outcome of patient in low systemic pressure: a case series

Purwoko[1], Septian Adi Permana[2], Fitri Hapsari Dewi[3], Prasdhika Arie Prihandana[4]

Author affiliations:

1. Purwoko, Department of Anesthesiology & Intensive Therapy, Faculty of Medicine, Universitas Sebelas Maret / Moewardi General Hospital, Surakarta, Indonesia; E-mail: purwokoanest@gmail.com
2. Septian Adi Permana, Department of Anesthesiology & Intensive Therapy, Faculty of Medicine, Universitas Sebelas Maret / Moewardi General Hospital, Surakarta, Indonesia; E-mail: septian.adi03@gmail.com
3. Fitri Hapsari Dewi, Department of Anesthesiology & Intensive Therapy, Faculty of Medicine, Universitas Sebelas Maret / Moewardi General Hospital, Surakarta, Indonesia; E-mail: fitrihapsarid@gmail.com
4. Prasdhika Arie Prihandana, Department of Anesthesiology & Intensive Therapy, Faculty of Medicine, Universitas Sebelas Maret / Moewardi General Hospital, Surakarta, Indonesia; E-mail: anestesisurakarta@gmail.com

Correspondence: Purwoko, **Phone:** +62811285616, **E-mail:** purwokonest@gmail.com

ABSTRACT

Mitral valve replacement (MVR) is a surgical procedure to treat mitral regurgitation (MR). As there is an increase in the afterload in the postoperative period, patients tend to have low cardiac output syndrome. This condition may limit oxygen delivery to body tissues. Improved venous saturation has been linked to positive neurological outcomes. Near-infrared spectroscopy (NIRS) is the new technique to monitor regional oxygenation in real time. This study reports on four patients who underwent MVR due to a combination of severe mitral stenosis (MS) and mild MR. All patients had complaints of dyspnea on exertion to unbearable chest pain. Physical and work-up examination led to a diagnosis of decompensated heart failure, concomitant valve disorder, fluid overload, and cardiomegaly. Preoperative catheterization to stratify the risks of the procedure was done on all four patients. The surgery planned was cardiopulmonary bypass (CPB) with standard monitoring and additional NIRS measurement. The measurement of mean arterial pressure (MAP) and NIRS were tightly monitored and maintained in each patient, with the use of vasoactive agents. All four patients suffered unstable hemodynamics and were admitted to intensive care unit with the support of mechanical ventilation and other supportive therapies. Cerebral perfusion can reach the baseline normal value even though in low cardiac output syndrome, and NIRS can predict the outcome of the patients better than the conservative monitoring.

Key words: CPB; Low Systemic Pressure; Cerebral perfusion; Mitral Valve Replacement; NIRS.

Citation: Purwoko, Permana SA, Dewi FH, Prihandana PA. How NIRS can predict the outcome of patient in low systemic pressure: a case series. Anaesth. pain intensive care 2023;27(6):757−762; **DOI:** 10.35975/apic.v27i6.2350

Received: May 29, 2023; **Reviewed:** September 20, 2023; **Accepted:** October 30, 2023

1. INTRODUCTION

The retrograde movement of blood, called mitral regurgitation (MR), from the left ventricle (LV) into the left atrium (LA) via the mitral valve (MV) produces a systolic murmur which is best heard at the apex of the heart with propagation to the left axilla. It is the most prevalent valvular anomaly in the world, affecting around 2% of the population and increasing in incidence with age.[1]

The degree, chronicity, comorbidities, and the cause of MR determine whether it should be treated medically or surgically. Surgical intervention is required in patients with acute, symptomatic MR or an effective regurgitant orifice of at least 40 mm^2. Patients with deteriorated LV function or an end-systolic diameter of 4.5 cm may also benefit from MR surgery. Patients with primary severe MR require surgery if their ejection fraction is greater than 30% and they are symptomatic or asymptomatic with an EF of 30-60%. Mitral valve repair goal is to have an adequate surface area of mitral valve leaflet coaptation (between 5 to 8 mm is ideal) and proper annular dilatation.[1]

Mitral stenosis (MS) is the most common valve disorder associated with rheumatic fever. Symptoms that arise depend on the severity of MS, including fatigue and dyspnea at first, then can cause paroxysmal nocturnal dyspnea, orthopnea, and shortness of breath at rest. The mortality rate alone is about 1% in mild MS and 5- 15% in severe MS. The left ventricular function progressively deteriorates in chronic MR. Progressive left ventricular dilatation raises wall tension, increasing systolic wall stress and afterload. The left ventricular after load increases rapidly following MVR without retaining the mitral valve system, and the left ventricle's response to this shift is dependent on annulo-ventricular continuity. Due to the low impedance route into the Left atrium is eliminated, the afterload is increased while the preload is reduced. This might be exacerbated by a residual gradient across the prosthesis, which could explain why many of these patients have "low cardiac output" despite a decent prosthetic performance.[2]

This malfunction may limit oxygen delivery to body tissues and maintaining venous saturation has been linked to positive neurological outcomes. As a result, achieving particular hemodynamic targets linked to oxygen supply should be part of postoperative intensive care in order to enhance patient outcomes.[3] However, It is difficult to adequately measure the condition of tissue oxygenation. The use of common hemodynamic indicators to assess tissue blood flow, such as blood pressure and pulse oximetry, is less than reliable. There might be microcirculatory perfusion deficits despite a seemingly normal macro perfusion. Nonetheless, microcirculation is difficult to assess at the bedside, and tissue perfusion is difficult to quantify using normal physiological monitoring methods. Other monitoring modalities used routinely in the critical care setting, in addition to blood pressure and heart rate, include intermittent measurement of serum lactate level, central venous pressure, and mixed venous oxygen saturation (SvO_2).[4] All of them have flaws and may not give a real-time and/or precise evaluation of tissue oxygenation status and may be insufficient for recognizing high-risk scenarios. Using devices that measure cardiac output by transpulmonary thermodilution (TPTD) or assess regional oxygenation using near-infrared spectroscopy (NIRS), technological improvements might provide new techniques of closer monitoring. The use of NIRS for combined cerebral and renal tissue oxygen saturation monitoring was associated with central venous oxygen saturation and cardiac output; poor cardiac output detection was associated with a distinct spectroscopic pattern in NIRS.[3]

In cardiac surgery, NIRS has conventionally been used to assess cerebral oxygen saturation, especially in congenital cardiac surgery and cardiac bypass surgery. It is presently being developed for noncardiac operations as well as a range of electrophysiology and critical care circumstances. Over the last decade, it has acquired recognition in the intensive care community.[4] We present four cases in which NIRS was successfully used.

2. CASE SERIES

2.1. Case-1

A 59-year-old female patient with severe MS and moderate MR was posted for mitral valve replacement (MVR). The patient had symptoms of chest pain that started 2 months back. There was a previous history of pulmonary tuberculosis cured with medication. There was a history of non-hemorrhagic stroke in August 2021, but currently no neurological deficit was found. NIRS value = Left 62, Right 40.

From the pre-surgery PA chest X-ray, cardiomegaly (CTR 62%) was found with left atrial hypertrophy (LAH), left ventricular hypertrophy (LVH) and pulmonary edema. Her echocardiography showed severe MS, moderate MR; mild pulmonary regurgitation (PR), atrial regurgitation (AR), tricuspid regurgitation (TR); spontaneous echo contrast (SEC) (+) in LA, and thrombus (+) in LAA.

Table 1: Characteristics of Case 1 (male, 59-year-old)

Parameter	Intraoperative	Postoperative	1st Day Postoperative
NIRS	L63, R59	L62, R58	L64, R61
Hemodynamic	BP78/44 mmHg MAP 55 mmHg	BP 71/49 mmHg MAP 55 mmHg	BP 84/49 mmHg MAP 60 mmHg
Support	• Dobutamine 7.5 µg/kg/min • Dopamine 7 µg/kg/min • Norepinephrine 0.2 µg/kg/min	• Dobutamine 7.5 µg/kg/min • Dopamine 7 µg/kg/min • Norepinephrine 0.2 µg/kg/min	• Norepinephrine 0.2 µg/kg/min

Table 2: Characteristics of Case 2 (female, 66-year-old)

Parameter	Intraoperative	Postoperative	1st Day Postoperative
NIRS	L69, R64	L69, R62	L66, R63
Hemodynamic	BP 84/54 mmHg MAP 64 mmHg	BP 79/48 mmHg, MAP 58 mmHg	BP 116/68mmHg, MAP 84 mmHg
Support	• Dopamine 7 µg/kg/min	• Dobutamine 7.5 µg/kg/min • Dopamine 7 µg/kg/min • Norepinephrine 0.2 µg/kg/min	• Norepinephrine 0.1 µg/kg/min

Catheterization laboratory result was normal coronary angiography, heavy MS, MR Grade III with BMW/MVR advice.

During surgery with CPB time 115 min; clamp time 93 min; EF value 36%; SVR 1300 Co 2.7, with blood pressure 78/44 mmHg; MAP 55 mmHg; NIRS = Left 63, Right 59, using dobutamine, dopamine, norepinephrine, and morphine infusions. After surgery the patient was shifted to the intensive care unit (ICU) with a mechanical ventilator and unstable hemodynamics.

In post operative period, the blood pressure only reached to 72/44 mmHg and the MAP was maintained at about 53 mmHg; and NIRS = L 64, R 59, with supportive inotropics dobutamine 7.5 µg/kg/min, dopamine 7 µg/kg/min, norepinephrine 0.2 µg/kg/min and morphine 15 µg/kg/min. Even though the MAP was under 60 mmHg but the NIRS values could still be maintained at over the baseline NIRS L 63, R 59. At night the patient became restless and hemodynamically unstable. Her BP was 71/44 mmHg; MAP 55 mmHg; NIRS = L 62, R 58. laboratory results Hb 9.6, HT 28 Al 17,200 platelets 65000 and given albumin 5% 250 ml, and morphine was reduced to 10 µg/kg/ h. After administration of albumin BP was 84/49 mmHg, and NIRS = L 64, R 61 (Table 1).

Next day after surgery the patient was fully awake, and the MAP gradually rose back to > 65 mmHg, Echocardiography results; LVEF 36% and the NIRS was still the same L 64, R 60. She was extubated and moved to the cardiac HCU in a stable condition without vasoactive and inotropic support (Table 1).

2.2. Case-2

A 59-year-old female with severe MS and moderate MR, was scheduled for MVR. She complained of dyspnea on exertion, but no history of chest pain or palpitations. Patient had chronic hypertension, and routinely received spironolactone 25 mg/day, bisoprolol 5 mg/day, furosemide 40 mg/day, warfarin 2 mg/day, and candesartan 4 mg/day. Physical examination revealed widened heart border, irregularly heart sounds and pansystolic murmur (4/6). Echocardiography resulted in severe MS, moderate MR, mild PR and TR, spontaneous echo contrast (SEC) (+), and soft thrombus in LAA. Preoperative coronary angiography was normal. Patient was informed about the procedure and written informed consent was obtained.

The surgery was planned under GA with cardiopulmonary bypass (CPB). The CPB time was 283 min, clamp time 205 min, EF value 36%, blood pressure 84/54 mmHg with NIRS = L69, R64, using heparin 7500 IU, dopamine 7 µg/kg/min, morphine 10-20 µg/kg/min, atracurium 10 µg/kg/min, and dexamethasone 5 mg. Patient was admitted to ICU postoperatively on mechanical ventilation (Table 2).

First day postoperative on routine monitoring showed unstable hemodynamics (BP 79/48 mmHg, MAP 58, SVR 1409, CO 2.7 and NIRS = L69, R62) with support using dobutamine, dopamine, and norepinephrine to maintain NIRS values according to baseline. Patient was extubated on first day postoperative and with uncompromised hemodynamic (BP 116/68 mmHg, MAP 84, NIRS = L66, R63) with support of vasoactive agent (Table 2).

2.3. Case-3

An 18-year-old male with severe MR due to prolapse A2, A3, P3 and mild tricuspid regurgitation, was scheduled for MVR. He complained of chest pain for the last couple of months. Patient had a history of rheumatic heart disease. Physical examination revealed rales on the lung bases, irregularly heart sounds and pansystolic murmur (4/6). Workup examination showed pulmonary edema, bilateral pleural effusion, and cardiomegaly (CTR 65%). Echocardiography result showed severe MR, mild AR and TR. Preoperative coronary angiography was normal.

CPB was planned under GA. The CPB time was 110 min, clamp time 85 min, with blood pressure 94/64 mmHg (MAP 74), NIRS = L60, R63 on dobutamine 7.5 µg/kg/min, dopamine 7 µg/kg/min, norepinephrine 0.2 µg/kg/min, morphine 10-20 µg/kg/min, dexamethasone 10 mg, and paracetamol 1 gram.

Table 3: Characteristics of Case 3 (male, 18-year-old)

Parameter	Intraoperative	Postoperative	1st Day Postoperative
NIRS	L60, R63	L58, R60	L61, R63
Hemodynamic	BP 94/74 mmHg MAP 74 mmHg	BP 84/46 mmHg MAP 60 mmHg	BP 93/54 mmHg MAP 67 mmHg
Support	• Dobutamine 7.5 µg/kg/min • Dopamine 7 µg/kg/min • Norepinephrine 0.2 µg/kg/min	• Dobutamine 10 µg/kg/min • Dopamine 10 µg/kg/min • Norepinephrine 0.2 µg/kg/min	• Norepinephrine 0.2 µg/kg/min

On the first postoperative day on routine monitoring, he had unstable hemodynamics (blood pressure 89/46 mmHg, MAP 60, SVR 1409, CO 2.7 and NIRS = L58, R60) with support using dobutamine, dopamine, and norepinephrine infusions to maintain NIRS values according to baseline. Patient was extubated on first postoperative day with uncompromised hemodynamics (blood pressure 93/54 mmHg, MAP 67, NIRS = L61, R63) with support of vasoactive agent (Table 3).

2.4. Case-4

A 51-year-old female with severe MS, mild MR, severe TR, mild AR and PR was scheduled for MVR. She complained of dyspnea on exertion and unexplained fatigue with palpitation (NYHA II). Patient was fitted with mitral valve prosthesis and had a history of heart disease for 7 y, for which she took ramipril 10 mg/day, furosemide 40 mg/day, bisoprolol 5 mg/day, warfarin 4 mg/day and spironolactone 50 mg/day. Patient was categorized as overweight (BMI 25.3 kg/m^2). Physical examination revealed widening heart border, pansystolic murmur (3/6), and diastolic murmur at apex (2/4)). There was cardiomegaly with all chambers dilated; with mitral valve prosthesis, and the apex projected at thoracic vertebra 7. Electrocardiography showed first degree atrioventricular block, right axis deviation, right ventricular hypertrophy, and incomplete right bundle branch block. Echocardiography revealed severe MS, severe TR, aortic-pulmonary regurgitation and mild MR and LV concentric remodeling (EF 57%) with high probability of pulmonary hypertension. Preoperative angiography concluded normal coronaries with MS CPB was planned to undergo general anesthesia. The CPB time was 111 min, clamp time 80 min, with blood pressure 90/50 mmHg (MAP 95), and NIRS = L60, R63. Drugs used included heparin, dopamine, morphine, dexamethasone, plasbumin 20% 100 ml and paracetamol 1 gram/8 h.

On first postoperative day the patient had unstable hemodynamics (BP 89/46 mmHg, MAP 60 mmHg, and NIRS = L68, R65) with support using dobutamine, dopamine, norepinephrine to maintain NIRS values according to baseline. Patient was extubated hemodynamic status stabilized (BP 100/80 mmHg, MAP 130 mmHg, NIRS = L70, R69) on vasoactive agents (Table 4).

3. DISCUSSION

The NIRS-derived regional oxygen saturation (rSO_2) value reflects local oxygen delivery and consumption. NIRS can track regional perfusion in many organ systems, such as the brain, kidney, and gut**.** MAP, arterial partial pressure of CO_2 ($PaCO_2$), cerebral metabolism and autonomic nervous system are believed to be the main regulators of cerebral blood flow (CBF). Maintaining CBF is critically important for brain function and tissue viability, especially for patients in the critical care unit. Continuous bedside monitoring of CBF could improve outcome by providing the ability to detect any signs of impaired CBF in the patients and allow for suitable interventions to prevent ischemia before permanent tissue damage occurs.[6] Baseline cerebral

Table 4: Characteristics of Case 4 (female, 51-year-old)

Parameter	Intraoperative	Postoperative	1st Day Postoperative
NIRS	L60, R63	L68, R65	L70, R69
Hemodynamic	BP 90/50 mmHg MAP 95 mmHg	BP 89/46 mmHg MAP 60 mmHg	BP 100/80 mmHg MAP 130 mmHg
Support	• Dopamine 7 µg/kg/min	• Dobutamine 10 µg/kg/min • Dopamine 10 µg/kg/min • Norepinephrine 0.2 µg/kg/min	• Dobutamine 10 µg/kg/min • Dopamine 10 µg/kg/min • Norepinephrine 0.2 µg/kg/min

oximetry normal values range from 60% to 80%; however, lower values of 55-60% are not considered abnormal in some cardiac patients.[5]

During anesthesia, MAP is often around 50 mmHg meaning that it remains unknown whether CBF is maintained, when an evaluation of CBF, e.g. by NIRS seems desirable.[7] NIRS is sensitive to changes in $PaCO_2$, detects hypoxemia, identifies cerebral autoregulation as well as regional distribution of CBF.[8] Measurement of MAP and the ratio of splanchnic tissue oxygen (StO_2s) to simultaneously measured cerebral tissue oxygen (StO_2c) during and after surgery can reduce the risk of a neurological deficit event because it can be a marker of reduced perfusion to the brain.[6,8-10]

NIRS use mathematical algorithms involving subtraction of values obtained from the emitters near and far from the photodetector to limit contamination from extracranial blood, and obtains a reading representative of cerebral oxygenation values and can be a more representative marker than MAP values regarding state of brain perfusion.[6,7,11]

These four cases show that in patients who had blood pressure and MAP less than 65, the NIRS showed values in accordance with normal baseline values. Cerebral perfusion can reach the baseline normal value even though in low cardiac output syndrome, and NIRS can predict the outcome of patient better than conservative monitoring.

4. CONCLUSION

Cerebral oximetry with near infra-red spectroscopy (NIRS) is useful for identifying real-time StO2c in the cerebrum, and to take appropriate measures to avoid poor neurological outcomes.

5. Conflict of interest

None declared by the authors.

6. Authors' contribution

All authors took equal part in the conduct of the cases as well as the preparation of this manuscript.

7. REFERENCES

1. Douedi S, Douedi H. Mitral Regurgitation. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK553135/
2. Rahman SM, Sazzad F, Wadud MA, Uddin MA, Roy SP, Sarkar PK, et al. Low Cardiac Output Syndrome: Incidence after Mitral Valve Replacement with or without Preservation of Mitral Valve Apparatus. Mymensingh Med J. 2021 Jan;30(1):164-170. [PubMed]
3. Gil-Anton J, Redondo S, Garcia Urabayen D, Nieto Faza M, Sanz I, Pilar J. Combined Cerebral and Renal Near-Infrared Spectroscopy After Congenital Heart Surgery. Pediatr Cardiol. 2015 Aug;36(6):1173-8. [PubMed] DOI: 10.1007/s00246-015-1139-z
4. Green MS, Sehgal S, Tariq R. Near-Infrared Spectroscopy: The New Must Have Tool in the Intensive Care Unit? Semin Cardiothorac Vasc Anesth. 2016 Sep;20(3):213-24. [PubMed] DOI: 10.1177/1089253216644346
5. DeMers D, Wachs D. Physiology, Mean Arterial Pressure. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK538226/
6. Lie SL, Hisdal J, Høiseth LØ. Cerebral blood flow velocity during simultaneous changes in mean arterial pressure and cardiac output in healthy volunteers. Eur J Appl Physiol. 2021 Aug;121(8):2207-2217. [PubMed] DOI: 10.1007/s00421-021-04693-6
7. Sørensen H. Near infrared spectroscopy evaluated cerebral oxygenation during anesthesia. Dan Med J. 2016 Dec;63(12):B5318. [PubMed]
8. Claassen JAHR, Thijssen DHJ, Panerai RB, Faraci FM. Regulation of cerebral blood flow in humans: physiology and clinical implications of autoregulation. Physiol Rev. 2021 Oct 1;101(4):1487-1559. [PubMed] DOI: 10.1152/physrev.00022.2020
9. Hawryluk G, Whetstone W, Saigal R, Ferguson A, Talbott J, Bresnahan J, et al. Mean Arterial Blood Pressure Correlates with Neurological Recovery after Human Spinal Cord Injury: Analysis of High Frequency Physiologic Data. J Neurotrauma. 2015 Dec 15;32(24):1958-67. [PubMed] DOI: 10.1089/neu.2014.3778
10. Brown CH, Neufeld KJ, Tian J, Probert J, Laflam A, Max L, et al. Effect of Targeting Mean Arterial Pressure During Cardiopulmonary Bypass by Monitoring Cerebral Autoregulation on Postsurgical Delirium Among Older Patients: A Nested Randomized Clinical Trial. JAMA Surg. 2019 Sep 1;154(9):819-826. [PubMed] DOI: 10.1001/jamasurg.2019.1163
11. Tosh W, Patteril M. Cerebral oximetry. BJA Educ. 2016;16(12):417–21. DOI: 10.1093/bjaed/mkw024

