

**EFFICACY OF NEAR INFRARED SPECTROSCOPY GUIDED  
ANESTHETIC MANAGEMENT TO PREDICT AND PREVENT  
THE INCIDENCE OF PERIOPERATIVE COMPLICATIONS IN  
PATIENTS PRESENTING FOR SURGICAL EXCISION OF  
CEREBRAL ARTERIOVENOUS MALFORMATION**

**Dr Jithumol Thankam Thomas**

DM Neuroanesthesia

July 2022



**SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND  
TECHNOLOGY, TRIVANDRUM**

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CEREBRAL ARTERIOVENOUS MALFORMATION**

A THESIS SUBMITTED BY

**Dr Jithumol Thankam Thomas**

TO

SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES  
AND TECHNOLOGY, TRIVANDRUM

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE AWARD OF

**DM**

July 2022

## DECLARATION BY THE STUDENT

### CERTIFICATE

I, Dr Jithumol Thankam Thomas, hereby certify that I had personally carried out the work depicted in the thesis titled, "Efficacy of near infrared spectroscopy guided anesthetic management to predict and prevent the incidence of perioperative complications in patients presenting for surgical excision of cerebral arteriovenous malformation."

No part of this thesis has been submitted for the award of any other degree or diploma prior to this date.



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## APPROVAL OF THE THESIS

The thesis entitled

Efficacy of near infrared spectroscopy guided anesthetic management to  
predict and prevent the incidence of perioperative complications in patients  
presenting for surgical excision of cerebral arteriovenous malformation

Submitted by

Dr Jithumol Thankam Thomas

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DM

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SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND  
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## ABBREVIATIONS

Sl.No	Abbreviation	Full Form
1.	AVM	Arteriovenous malformation
2.	ASA	American Society of Anesthesiologists.
3.	BP	Blood Pressure
4.	CAH	Controlled Arterial Hypotension
5.	CBF	Cerebral Blood Flow
6.	CCF	Congestive Cardiac Failure
7.	CO <sub>2</sub>	Carbon Dioxide
8.	CBF	Cerebral Blood Flow
9.	CMR	Cerebral metabolic rate
10.	CMRO <sub>2</sub>	Cerebral metabolic rate of oxygen
11.	CPP	Cerebral Perfusion Pressure
12.	CT	Computed Tomography
13.	EDH	Extradural hematoma
14.	EtCO <sub>2</sub>	End tidal carbon dioxide
15.	HR	Heart Rate
16.	ICP	Intracranial pressure
17.	N <sub>2</sub> O	Nitrous oxide
18.	NIRS	Near Infrared Spectroscopy
19.	MAP	Mean Arterial Pressure

20.	mRS	Modified Rankin scale
21.	rSO <sub>2</sub>	Regional cerebral oxygen saturation
22.	PO <sub>2</sub>	Partial pressure of oxygen
23.	PCO <sub>2</sub>	Partial pressure of carbon dioxide
24.	SD	Standard Deviation
25.	SM	Spetzler Martin
26.	ScO <sub>2</sub>	Cerebral oxygen saturation
27.	SBP	Systolic blood pressure
28.	SNP	Sodium Nitroprusside
29.	SjVO <sub>2</sub>	Jugular venous oxygen saturation

## **ABSTRACT**

**TITLE- Efficacy of near infrared spectroscopy guided anesthetic management to predict and prevent the incidence of perioperative complications in patients presenting for surgical excision of cerebral arteriovenous malformation.**

### ***Background:***

Brain arteriovenous malformations (AVMs) are anatomically characterised by a tangle of thin-walled vessels that connect the high-pressure arterial circulation to the low-pressure venous system without an intervening capillary network. Pre-excision, they present a low resistance circulation which renders the perinidal tissues susceptible to ischemia. However, post excision of AVM, there can be increase in the blood flow resulting in the development of diffuse cerebral bleeding and brain edema. In the perioperative period, continuous real-time monitoring of cerebral oxygenation enables the anesthesiologist to alter blood pressure and oxygenation targets as the resection or occlusion of the AVM happens. In addition, postoperatively, as the brain acclimatises to new parameters, intense monitoring of cerebral oxygenation will detect any ischemic or hyperemic changes in the perinidal brain tissue.

### ***Aims & Objectives:***

We hypothesised that NIRS-guided perioperative management can aid in prediction and prevention of perioperative complications in patients presenting for surgical excision of cerebral AVMs. In addition, we intended to identify a threshold value of rSO<sub>2</sub> to predict the incidence of perioperative complications.

### ***Methods and Material:***

This was a prospective observational study involving 15 patients undergoing supratentorial AVM resection surgeries. rSO<sub>2</sub> and hemodynamic monitoring were done intraoperatively and postoperatively for 12 hours. A drift in rSO<sub>2</sub>>12% and perioperative events were recorded and analyzed. For analysis, patients were categorized into two groups, Group A - Patients without complications and Group B - patients who had complications postoperatively.

### ***Results:***

Five patients developed postoperative complications (33.3%) and were included in group B and the rest in group A. Fifty three percent of the AVMs were SM grade II, 26.6% were SM grade I, and 21.4% were SM grade III. Group B had higher number of grade III AVMs as compared to group A (60% vs 20%). Post AVM excision, there was a significant increase in the mean ipsilateral rSO<sub>2</sub> drift from the baseline in Group B patients, as compared to Group A [ $12.01 \pm 2.63$  % vs  $4.98 \pm 5.7$  %, (p= 0.022)] with 80% of the patients having an ipsilateral mean rSO<sub>2</sub> drift of >12% in Group B. Postoperatively, patients in group B had a significant negative mean rSO<sub>2</sub> drift as compared to Group A [ $14.96 \pm 0.080$  % vs  $6.88 \pm 4.5$  %, (p<0.01)] with 80 % of the patients in Group B having an ipsilateral rSO<sub>2</sub> drift of >12%. Thus with the help of NIRS rSO<sub>2</sub> drift we were able to timely detect both hyperemia and ischemia and intervene appropriately. The incidence of complications in our study was 33.3%. Generalised seizures were seen in four patients (26.6%), ipsilateral EDH with one episode of focal seizures in one patient (6.6%), global cerebral oedema in one patient (6.6%), ipsilateral venous infarct postoperatively, delayed extubation with a new

onset focal neurological deficit in one patient(6.6%).Two patients were reintubated due to recurrent seizures(13.3%). Two patients (13.3%) had residual AVMs in the post-operative angiogram.

***Conclusions:***

Near Infrared Spectroscopy can help detect changes in regional cerebral oxygenation caused by hyperemia or ischemia during cerebral AVM resection, and any significant drift could alert the physician to implement a timely intervention.

- In patients undergoing excision of cerebral AVMs, an intraoperative ipsilateral rSO<sub>2</sub> drift > 12 % should be treated with caution and close observation in the postoperative period as these patients tend to develop complications in the postoperative period.
- However, an ipsilateral rSO<sub>2</sub> drift >14.9% from the baseline in the postoperative period warrants immediate evaluation and appropriate management as it forecasts the incidence of an adverse clinical event in the near future.



**INTRODUCTION**

## **1. INTRODUCTION**

Arteriovenous malformations (AVMs) are abnormal communications between small arteries and veins without intervening capillaries, thus producing a low resistance and high-flow shunt.(1)These may occur anywhere in the human body but are often seen in the brain and spinal cord. Brain AVMs deprive the surrounding tissues of blood supply and produce venous hypertension and localized cerebral edema.(2) Large AVMs are known to cause congestive cardiac failure (CCF) by overloading the heart.(2) The high-flow, low-resistance shunt offered by the AVM results in chronic hypoperfusion of adjacent brain tissue and a shift of the autoregulatory curve to the left in this zone. (1)The treatment of AVMs is based on several factors such as the patient's age, neurological condition, and characteristics of AVMs. They may include any combination of microsurgical excision, endovascular embolisation and stereotactic radiosurgery.(1)

The perioperative morbidity and mortality encountered after AVM resection or obliteration are mainly attributed to changes in the cerebral circulation caused by the removal of a low resistance AVM circuit. The primary pathophysiological phenomena causing circulatory failure in post-AVM resection patients are the normal perfusion pressure breakthrough (NPPB) and occlusive hyperemia.(3) The NPPB theory postulates that postoperative haemorrhage and oedema are caused by an autoregulatory failure in the perinidal brain tissues. Chronic hypoperfusion in the perinidal brain results in chronic vasodilation of the perinidal arteries, resulting in the inability of vessels to vasoconstrict in response to the increased cerebral blood flow (CBF) due to resumption of normal perfusion pressure after the AVM resection.(4)

Therefore, a proposed preventative strategy for acute postoperative hyperemia is staged occlusion or maintaining low normal blood pressure (BP) after surgical resection of the AVM.(5,6)

On the other hand, the occlusive hyperemia theory states that malignant postoperative haemorrhage and oedema are caused by either arterial stagnation and obstruction or venous outflow obstruction following resection of the AVM, resulting in perinidal hypoperfusion and hypoxia.(7) Induced hypotension can be detrimental in such cases. Therefore, the treatment strategy in this scenario is to induce hypertension to improve the CBF.(7) Additionally, it has frequently been reported that AVM veins are delicate and challenging to cauterise intraoperatively, thereby leading to higher blood loss.(6) Also, these AVM vasculatures lack cerebral autoregulation. As a result, controlled arterial hypotension (CAH) is a useful strategy to lower blood flow during AVM surgery. However CAH can be dangerous, especially when blood pressure falls below the lower limit of autoregulation, leading to cerebral ischemia and neuronal damage.(6)

The crux of perioperative management is to balance optimal cerebral oxygenation and prevent cerebral hyperemia. Thus, monitoring cerebral oxygenation is beneficial in preventing any ischemic events or hyperemic events in the perioperative period. Near Infrared Spectroscopy (NIRS) is a non-invasive monitor that helps to detect cerebral ischemia or hyperemia by measuring the regional cerebral oxygen saturation(rSO<sub>2</sub>). (8) Despite the proven beneficial role of NIRS as a monitor of cerebral perfusion and oxygenation, studies on the role of NIRS in cerebral AVM surgeries are sparse.

***Hypothesis:***

- NIRS-guided perioperative management can help predict and prevent perioperative complications in patients presenting for surgical excision of cerebral AVMs.

***Aims and Objectives:***

1. The primary objective was to study the correlation between intraoperative changes in rSO<sub>2</sub> and postoperative neurological complications such as cerebral ischemia, cerebral oedema, haemorrhage and seizures
2. The secondary objective was to identify a threshold value of NIRS to predict the incidence of perioperative complications such as cerebral ischemia or hyperemia in this subset of patients.



**LITERATURE REVIEW**

## 2. LITERATURE REVIEW

Brain arteriovenous malformations (AVMs) are a tangle of thin walled vessels without an intervening capillary network, connecting the high-pressure arterial circulation to the low-pressure venous system. They typically present between 20-45 years of age with a peak in the 4th decade.(9) About 18-20% of cerebral AVMs are diagnosed during infancy and childhood. Patients usually present with symptoms such as intracranial bleed (30-86% in adults, and 75-80% in pediatrics, seizure (8-46%), focal neurological deficits (4-23%),hydrocephalus or rarely congestive cardiac failure(CCF).(10) Cerebral injury may occur due to (i) “Steal” phenomenon, (ii) Ischemia from failure of perfusion from CCF, (iii) Hemorrhagic infarction from thrombosis of the aneurysm of the great vein of Galen, (iv) Cerebral atrophy and (v) Alterations of flow caused by surgery.(1) Majority of intracranial AVMs are supratentorial (70-97%), followed by infratentorial (3-30%) or in deeper brain structures (5-18%).(9) Steal phenomenon occurs when there is shunting of high flow blood across a low-resistance shunt, thereby bypassing the capillaries.(11)

**Anatomy of AVMs** - Feeding arteries, nidus, and draining veins are the three parts of an AVM. (12) The absence of a capillary bed and the existence of one or more direct arteriovenous connections allow for high-flow arteriovenous shunting through small feeding arteries without a muscularis layer, which are the physical characteristics of an AVM. As a result, the feeding and draining vessels may experience structural alterations as a result of this high-flow shunt, leading to arterial smooth muscle hyperplasia accompanied with fibroblasts and connective tissue

components known as fibromuscular cushions.(12) AVMs have different microscopic characteristics depending on what part of the lesion is sampled. The arterial feeders have muscular elastic walls, while the venous elements have thin collagenous walls. The parenchymal components of the AVM typically exhibit hemosiderin staining, gliosis, and maybe nonfunctional.

**Physiology of AVM** - The pressure in feeding arteries is lower than systemic pressure, while the pressure in draining veins is elevated. Since the arterial feeders and draining veins of the AVM are derived from normal cerebral circulation, the surrounding normal brain tissue suffers from reduced cerebral perfusion pressure (CPP). Thus the perinidal brain tissue areas are rendered highly vulnerable to ischemia. The shunt results in chronic hypoperfusion of adjacent brain tissue with a leftward shift of the autoregulatory curve.(13)

Studies however suggest that vascular reactivity to carbon dioxide(CO<sub>2</sub>) is preserved, indicating that autoregulation has been shifted to the left rather than completely abolished.(14) The tissue adjacent to the AVM has a lower tissue oxygen tension than normal, but normal pH and PCO<sub>2</sub>, suggesting an adaptive capillary exchange mechanism which maintains normal CO<sub>2</sub> clearance despite chronic hypoxia. During resection, the tissue oxygen tension and pH increases while the PCO<sub>2</sub> decreases.(15)

At the same time, AVMs are characterised by the development of diffuse bleeding and brain edema intraoperatively or postoperatively after their abrupt termination. Though the cause often may be the presence of minimal residual nidi, the characteristic hemodynamic changes that occur after AVM resection have also

been implicated. i.e the normal perfusion pressure breakthrough (NPPB) hypothesis and the ‘occlusive hyperemia’ hypothesis.(4,7)

### **Normal Perfusion Pressure Breakthrough**

According to this mechanism, AVM are large arteriovenous conduits with no resistance to blood flow, as compared to the small surrounding vessels with high resistance to blood flow. These small vessels remain maximally dilated to divert blood from the AVM to the surrounding brain hemisphere. This chronic dilatation in these vessels in the presence of ischemia leads to loss of autoregulatory failure. Thus, when the AVM is suddenly obliterated, thereby raising the resistance infinitely high in those vessels, the flow is redirected to the adjacent ischemic brain at a normal perfusion pressure. The autoregulatory control at the arteriolar level, having been chronically dilated, cannot adequately increase the resistance to this new perfusion pressure, which in turn leads to breakthrough with resultant edema or hemorrhage.(4)

### **Occlusive Hyperemia Theory**

This theory states that complications of hemorrhage and/ or edema associated with the resection of high-flow AVM's are the result of two separate but interrelated mechanisms involving both the arterial feeders and the venous drainage.

These mechanisms are:

- 1) Stagnation of arterial flow in former AVM feeders and their parenchymal branches with subsequent worsening of the existing hypoperfusion and ischemia and subsequent hemorrhage and/or edema into these areas; and

- 2) Obstruction of the venous outflow system in the parenchyma adjacent to the AVM with subsequent passive hyperemia, engorgement, and further arterial stagnation.(7)

Also, dysautoregulation at the microcirculation level may play a role.

During AVM obliteration, appropriate blood pressure titrations are required during various stages of the procedure. While it is prudent to maintain adequate perfusion pressure intraoperatively to prevent cerebral ischemia in the adjacent maximally vasodilated areas; it is also crucial as the obliteration progresses that the mean arterial pressure be lowered or an increase from baseline prevented in order to avoid hyperemia and bleeding.(3) The advent of titratable anesthetic and vasoactive agents along with continuous real time monitoring of cerebral oxygenation enables the anesthesiologist to alter blood pressure targets as the resection evolves. Post-excision as the brain acclimatizes to new parameters, appropriate blood pressure optimization and close intense monitoring is warranted.

AVM can be treated using a number of different modalities, such as (a) Conservative care (b) Microsurgical removal with or without endoscopic aid (c) Endovascular embolization (d) and Stereotactic radiosurgery. (1) When the risk of surgery is lower than the danger of the natural course, surgical resection is recommended for surgically accessible lesions in non-eloquent regions. In order to treat acute hydrocephalus or an intracerebral hematoma that poses a serious danger of brain herniation, emergency surgery is recommended. Patients with Grade I and II AVMs have reported rates of morbidity and mortality after AVM excision of 1% and

0.5 %, Grade III patients have reported rates of 18.9 % and 2.7%, and Grade IV and V patients have reported rates of 25.6 % and 7.7 %, respectively. (16)

Endovascular embolisation aims to reduce the shunt so as to prepare the patient for surgery, obliterate the lesion completely, and to embolise the deeper feeder vessels without causing damage to the eloquent brain areas, and to reduce the hyperemic complications. However, endovascular embolisation is not without risk. Frizzel RT and associates reported embolisation in 1246 patients with brain AVMs. They showed cure in 5% patients, a 8% permanent morbidity and 1% mortality.(17) Despite complications, studies suggest that endovascular embolisation is safe, cost-effective and shows better results when combined with surgery than surgery alone.(18)

### **Effect of Anesthetic drugs on Cerebral physiology**

The majority of intravenous anaesthetics slow down brain metabolism (CMR). An increase in vascular resistance and a decrease in cerebral blood flow occur in conjunction with this depression (CBF). Contrarily, with the exception of N<sub>2</sub>O, the majority of inhalation anaesthetics raise CBF (vasodilator action) while lowering CMR. This impact is not always associated with a breakdown in flow-metabolism. (19) Isoflurane is still the preferred inhalational agent for use in neurosurgical patients due to its constrained capacity to raise intracranial pressure (ICP) and cerebral blood flow (CBF), as well as the fact that its potent cerebral metabolic depressive effects are thought to have the best cerebral protective effects.

On the other hand, with the exception of ketamine, intravenous anaesthetics reduce CBF and CMRO<sub>2</sub> in a dose-dependent manner. Etomidate may prevent ischemia due

to its ability to stabilise membranes and restrict the release of free fatty acids. (20,21) When the brain is at risk of focal ischemia during AVM embolisation and/or surgical resection, barbiturates, etomidate, and propofol have been demonstrated to offer brain protection. (22)

Aside from their impact on CBF, anaesthetics that dilate blood vessels may cause the steal phenomenon, whereas those that constrict blood vessels have the reverse effect, causing inverse theft, and may protect the brain or lessen harm. Opioids can have a variety of effects on CBF, CMRO<sub>2</sub>, and ICP, although fentanyl and droperidol (neuroleptanesthesia) have no discernible impact on these measurements and can be administered safely during embolization. (22) To maintain mean blood pressure, it is advised to provide these opioids slowly whenever possible.(23)

If respiration is well-controlled and an increase in PaCO<sub>2</sub> is avoided, muscle relaxants—with the exception of succinylcholine—cause a modest change in CBF and ICP. However, succinylcholine increases ICP due to fasciculation. (22)

It is crucial to understand the effects of the medications employed on cerebral hemodynamics since we have planned to conduct the current investigation under anaesthesia intraoperatively with Propofol as an induction agent and Sevoflurane for maintenance.

***Effects of Propofol on Cerebral Circulation:***

Propofol produces dose-related reduction in global CBF by 50 to 60%. (24,25) This variation in regional cerebral blood flow (rCBF) reduction has been confirmed with Positron Emission Tomography (PET) studies which demonstrated

large preferential decrease in the medial thalamus, cuneus and precuneus, and posterior cingulate, orbitofrontal, and right angular gyri. (26) The CBF decrease with propofol is mainly due to its metabolic depressant effect. Propofol depresses CMR (Cerebral Metabolic Rate) and does this differently according to region.(27) The metabolism in the cerebral cortex decreases (by 58%) more than the sub-cortical brain areas (by 48%). In patients with intracranial tumors, Intracranial Pressure (ICP) was shown to be lower and Cerebral Perfusion Pressure (CPP) higher in patients anesthetized with propofol when compared with those anesthetized with volatile anesthetics (isoflurane or sevoflurane).(28) MAP usually decreases with administration of propofol, which necessitates strict maintenance of MAP/ CPP, even more important in patients with elevated ICP.

***Effects of Sevoflurane on Cerebral Circulation:***

The study by Kaisti et.al. using PET showed either a decrease or no change in global CBF occurred with sevoflurane.(24) MAP decreased significantly with sevoflurane in the study by Kaisti et.al, whereas MAP was found to be unchanged in the study by Schlunzen et.al.(24,29) Thus, as long as MAP is maintained, global CBF remains unchanged with use of sevoflurane, though heterogeneity of the rCBF response was seen; with increase in rCBF seen in the anterior cingulate and a reduction in the cerebellum.

During propofol-induced isoelectric EEG, sevoflurane at both 0.5 and 1.5 MAC produced a smaller increase in Vmca (MCA mean flow velocity) than isoflurane, suggesting lesser vasodilating potential of sevoflurane than isoflurane.(30) Sevoflurane at 1 MAC was reported to decrease rCMRg (regional

metabolic rate for glucose) in all regions of the brain, with the most marked reduction seen in the lingual gyrus (by 71%), occipital lobe (by 68%), and thalamus (by 68%).(31) Sevoflurane, with or without N<sub>2</sub>O, produces no or small increases in ICP seen in animal studies as well as in humans. These effects reinforce the fact that sevoflurane does not affect the CBV (Cerebral Blood Volume) though it causes reduction in CBF.(32)

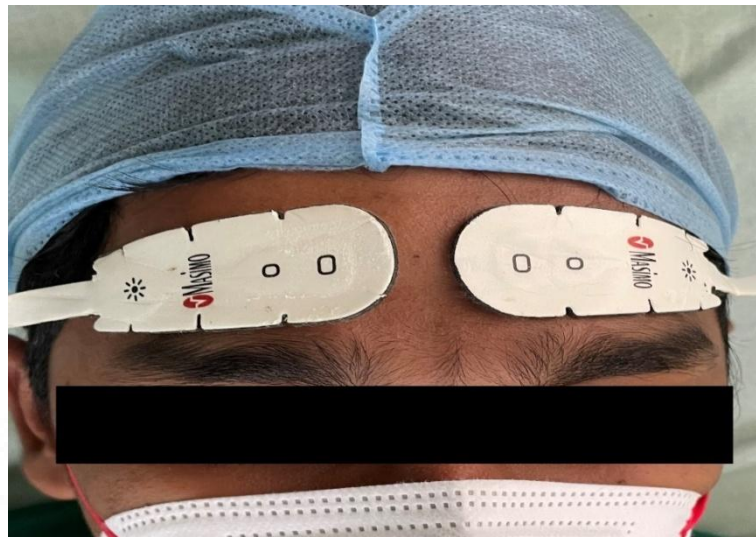
Various techniques have been employed for the early detection of perioperative cerebral ischemia and hypoxia like electroencephalography (EEG), Transcranial doppler (TCD) velocity measurement and brain tissue oxygen tension (PbtO<sub>2</sub>). However these techniques may often be invasive or may require expertise, learning curve and trained personnel. Cerebral near-infrared spectroscopy (NIRS) is a novel technique being increasingly used as a surrogate to monitor brain oxygenation. It is a non-invasive optical technology that has emerged as a monitor of cerebral perfusion. Near-infrared light can penetrate the human skull and using methods of spectroscopy (near-infrared spectroscopy (NIRS)) — provides non-invasive access to determine regional oxygen saturation (rSO<sub>2</sub>) of the brain. This derived index reflects approximately 70% venous and 30% arterial cortical blood, but varies considerably between individuals and because of extracerebral signal contribution, emphasizing that relative changes rather than absolute values are of interest.(8,,33,34). NIRS-guided cerebral oximetry is associated with regional cerebral perfusion and/or oxygenation in tissue underlying the optodes.

Utilizing NIRS during neurovascular surgeries gives accurate, ongoing, real-time data on cerebral oxygenation. (35) NIRS provides a good reflection of changes

in brain tissue oxygen tension. (36) The method has been widely applied, from neonatal critical care through adult surgery, to detect clinically silent bouts of cerebral ischemia by monitoring regional cerebral oxygen saturation (rSO<sub>2</sub>).

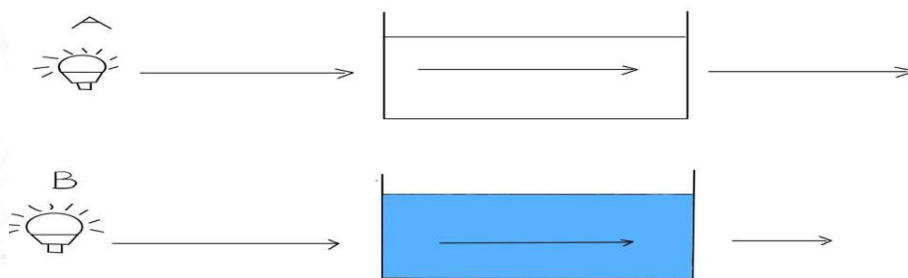
**Principle of Cerebral Oximetry** - Since most biological tissues, including bone, are transparent to infrared light, haemoglobin and cytochrome molecules will be predominantly responsible for light absorption as it passes through the tissue. Oxyhemoglobin and deoxyhemoglobin have different absorption spectra in the NIR range of 700–1,000 nm, which changes the reflected NIRS signal. Estimating brain oxygen saturation is based on the ratio of oxygenated to nonoxygenated haemoglobin (37), with measurement determined using an algorithm based on the Beer-Lambert law (38). Optodes, which are positioned on the forehead above the brow, transfer infrared light through the skull and into the frontal cortex by a few centimetres (39). The curvilinear beam is subject to absorption and scatter, and surface detectors then capture the reflected photons.

Due to the poor signal-to-noise ratio because of the low intensity of transmitted light, most commercially available devices use reflectance-mode NIRS in which receiving optodes are placed ipsilateral to the transmitter. This arrangement exploits the fact that photons traverse an elliptical path when transmitted through a sphere in which the mean depth of penetration is proportional to the transmitter and receiver optode separation distance(Fig 1).

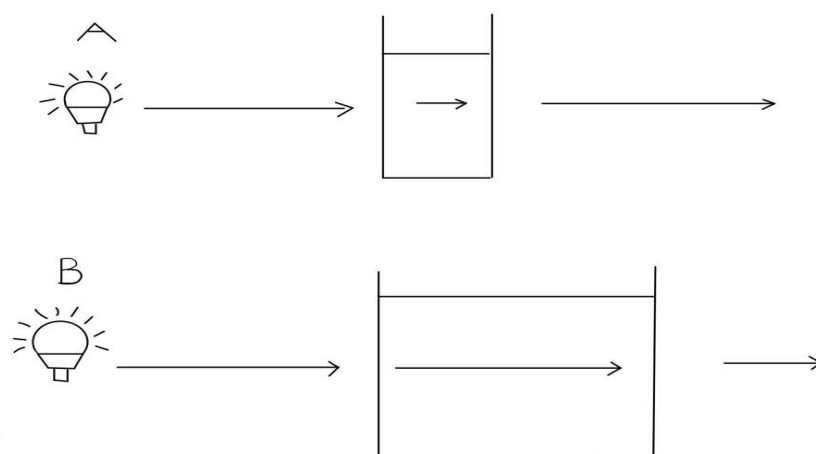


**Fig 1- NIRS sensors placed on forehead**

On the Beer-Lambert law, NIRS is founded. Beer's law indicates that as a substance's concentration grows, the amount of light that is transmitted falls exponentially, as seen in Fig 2. According to Lambert's law, the amount of light that is transmitted diminishes exponentially as the amount of material it passes through rises, as illustrated in Fig. 3



**Fig 2:Beer's law (intensity of transmitted light decreases exponentially as the concentration of the solute increases)**



**Fig 3: Lambert's law (intensity of transmitted light decreases exponentially as the distance travelled by the light increases)**

The majority of devices are continuous wave (CW) monitors with a transmitter-detector distance (about 4 cm) that enables the separation of deeper cerebral impulses from surface extracranial signals (40). The CW devices do not measure the absolute amounts of oxy- and deoxyhemoglobin; instead, they measure haemoglobin saturation based on the red: infrared ratio. By maximising the distance between the emitter and the detector, employing numerous wavelengths and detectors, or figuring out the absolute chromophore levels, one can increase spatial resolution. Based on absolute values of oxygenated, deoxygenated, and total haemoglobin, frequency domain (FW) and temporal domain techniques estimate ScO<sub>2</sub> and are believed to account for variance in volume of cerebral blood. (40) To determine tissue oxygen index, the FW-NIRS devices use a mathematical model based on photon diffusion theory to account for individual scatter (TOI) as well as total haemoglobin index (THI).

### **Correlation between NIRS and Cerebral oxygenation**

Meeri et. al. did a study to assesses CBF by diffuse correlation spectroscopy (DCS) and oxy and deoxy- hemoglobin measurement by NIRS. DCS/NIRS based measurements of CBF and oxygenation from frontal lobes were compared with concurrent xenon-enhanced computed tomography (XeCT) in patients during induced blood pressure changes and carbon dioxide arterial partial pressure variation. (41) Seven patients were included for the study. Relative CBF measured by DCS ( $rCBF_{DCS}$ ) and changes in oxy-hemoglobin ( $DHbO_2$ ), deoxy-hemoglobin ( $DHb$ ), and total hemoglobin concentration ( $DTHC$ ), measured by NIRS, were continuously monitored throughout XeCT during a baseline scan and a scan was repeated after the intervention.  $rCBF$  measured by DCS and  $rCBF$  XeCT showed good correlation among the patients. Moderate correlation was found between  $rCBF_{DCS}$  and  $DHbO_2/DTHC$ . Both NIRS and DCS independently were able to differentiate the effects of xenon inhalation on CBF. The authors concluded that DCS measurements of CBF and NIRS measurements of tissue blood oxygenation could provide a noninvasive and continuous bedside monitoring for CBF management in neurocritical care patients.

Pollard et. al. did a study to validate NIRS for brain oxygenation monitoring.(42) Twenty two conscious, healthy volunteers were studied, by breathing hypoxic gas mixtures. Using 12 subjects (referred as training group), they developed an algorithm based on the mathematic relationship which converts detected light from the field surveyed by the probe to cerebral hemoglobin oxygen saturation ( $CSfO_2$ ). The authors correlated the oximeter results with the estimated

combined brain hemoglobin oxygen saturation  $CS_{\text{combo}2}$ , where  $CS_{\text{combo}2} = SaO_2 \times 0.25 + SjO_2 \times 0.75$  and  $SjO_2$  = jugular venous saturation). The algorithm was then validated in the 10 volunteers. A close association was found between  $CS_{fO_2}$ , and  $CS_{\text{combo}2}$ . The conclusion of the study was that continuous monitoring with cerebral oximetry can accurately recognize decreasing cerebral hemoglobin oxygen saturation produced by systemic hypoxemia.

Marc et.al. did a study by using frequency domain near-infrared spectroscopy to determine the ratio of arterial and venous blood monitored by cerebral oximetry during three clinical situations: normoxia, hypoxia and hypocapnia.(43) They studied 20 anesthetized children aged < 8 years with congenital heart disease of varying arterial oxygen saturation ( $SaO_2$ ) during cardiac catheterization. Cerebral oxygen saturation ( $ScO_2$ ),  $SaO_2$ , and jugular bulb oxygen saturation ( $SjO_2$ ) were measured by frequency domain NIRS and blood oximetry at normocapnia room air, normocapnia 100% inspired  $O_2$ , and hypocapnia room air. The study found arterial contribution of  $16 \pm 21\%$  and venous contribution of  $84 \pm 21\%$ , to cerebral oximetry. Though the contribution was similar among the three conditions of recording, significant variation was observed among the subjects (range, ~ 40:60 to ~ 0:100, arterial: venous). The authors concluded that because of biologic variation in cerebral arterial/venous ratios, use of a fixed ratio is not recommended. Though previous studies have demonstrated a predominant contribution from venous system (70%-80%).

By contrasting the distinct absorbance patterns of oxygenated and non- (44) Tissue oxygen extraction will rise to sustain cerebral metabolism as cerebral blood

flow (CBF) declines, which will eventually lead to a drop in hemoglobin saturation. Therefore, rSO<sub>2</sub> is an indirect measurement of CBF and offers a "index" of organ ischemia when there is a steady metabolic rate. (8) The method has been widely applied, from neonatal critical care to adult surgery, and enables for the detection of clinically silent episodes of cerebral ischemia. However, a variety of parameters, such as hematocrit, hemoglobin-O<sub>2</sub> binding affinity (P50), inspiratory oxygenation, and ventilation, may affect oxygen transport and cerebral oxygen saturation. Also of note is the fact that CBF can itself be influenced by posture, head positioning and anatomical variation. (45,46)

Potentially, cerebral oximetry and neurological monitoring will redefine how intraoperative hypoxia and hypotension are managed. (47) A therapeutic endpoint for clinical intervention, such as the application of vasopressor treatment to raise cerebral perfusion pressure, is provided by intraoperative rSO<sub>2</sub> monitoring (CPP). However, the perception that blood pressure control alone is sufficient to maintain cerebral perfusion in all individuals is constrained in the absence of direct assessment of cerebral perfusion. It is not possible to make the clinical premise that an increase in arterial pressure and CBF occur simultaneously.

#### **Advantages and Limitations of NIRS:**

NIRS has numerous advantages such as being non invasive, ability to simultaneously sample multiple regions of interest with high temporal resolution, and being user friendly. The greatest advantage of NIRS is ease of use; placement of two cerebral oximeter probes on the forehead is fast and easy. Though NIRS has multiple advantages, it is not without limitations. NIRS values can be confounded by

a number of factors, such as by contamination from extracerebral blood from scalp or subdural hematoma, presence of non-heme tissue chromophores etc. The spatial resolution provided by NIRS is restricted. It can sense the outer 1-4 mm of the cortical surface only.(48) Also, the area between light emitter and detector only contributes to the NIRS value.(49)

### **NIRS monitoring in AVM procedures**

Real-time monitoring of cerebral oxygenation is relevant in AVM resections and AVM embolization procedures, where perioperative management is focused on the prevention of cerebral hypoxia and at the same time prevention of cerebral hyperemia leading to haemorrhage.

There have been studies in the past where intraoperative monitoring of brain tissue oxygenation in AVM resection has been performed with cerebral oxygenation monitors like brain tissue oxygen tension (PbtO<sub>2</sub>) and jugular venous oxygen saturation (SjVO<sub>2</sub>). (50,51)

Arikan et al studied brain oxygenation in twenty-two patients with supratentorial AVMs . Tissue hypoxia was detected in 63.6% of the catheters placed in the perinidal area and in 43.8% of catheters placed in a distant area.They thus concluded that AVM excision significantly improved oxygenation both around the AVM and in the distant area. These studies have revealed that the baseline hypoxia in the perilesional area reverted after surgical excision. The resection of the lesion can induce a moderate or significant hyperemic response resulting in cerebral hemorrhage.(50)

Asgeri et al in their study, measured cortical oxygen saturation (SaO<sub>2</sub>) and BV (intracapillary total hemoglobin concentrations) with NIRS, in areas adjacent to the arteriovenous malformation for 20 patients, before and after resection. The differences between pre- and post-excision values for both parameters were observed to be statistically significant (P<0.01). Postoperatively, two patients developed intracerebral hemorrhage or severe edema. Both demonstrated high postexcision/preexcision (P-P) ratios for SaO<sub>2</sub> and BV. They thus concluded that intraoperative NIRS is able to detect the hyperemic status of adjacent cortex after arteriovenous malformation resection.(51)

Several complications have been reported post AVM excision which significantly affect the overall morbidity, mortality and patient outcome. Badjer et al reported a 48% incidence of intracranial haemorrhage, 44% incidence of seizures, 34% incidence of progressive deficits, 37% incidence of angiographic steal, 13% intracerebral hematoma and 8-21% incidence of hyperemic complications following treatment of AVMs. They observed 5% incidence of hyperemic complications in AVMs less than 3 cm and 35% incidence in AVMs >6 cm in size. In addition, they reported a higher incidence of hyperemic complications in AVMs with deep perforators.(52) Morgan et al. reported a 3% incidence of hyperemic complications which was seen mainly in AVMs >4 cm size and in patients with increased post excision blood pressures.(53) Non-invasive cerebral oximetry monitors like NIRS can provide information regarding the cerebral oxygenation state and help to optimally tailor the management.

Deruty et al. evaluated a group of 67 patients who had cerebral AVMs treated using a variety of techniques, paying close attention to any treatment-related problems. 19 patients (28%) experienced a worsening following treatment; this was either a modest deterioration (19%), a neurological deficiency (4%), or death (4 percent). In 17% of all instances that had surgery, resection was the cause of mild worsening. Twenty five percent of all cases of embolization resulted in complications (minor or neurological deficit, or death). The normal perfusion pressure breakthrough syndrome, abnormalities in venous drainage (venous overload or occlusive hyperaemia), and retrograde thrombosis of the feeding arteries were the main haemodynamic mechanisms for problems. (54) With rSO<sub>2</sub> monitoring in NIRS, these issues may be caught early.

Cerebral oximetry monitoring is a crucial protection for cerebral function since it can identify otherwise clinically silent bouts of cerebral ischaemia in a number of clinical contexts. Episodes of angiographic cerebral vasospasm were highly correlated with a decline in the trend of the ipsilateral NIRS signal in a study of individuals with subarachnoid haemorrhage. (55) Also showing real-time detection of intracerebral ischemia, the degree of spasm (particularly greater than 75% artery diameter decrease) was linked to a bigger reduction in same-side NIRS signal.

NIRS has also shown good correlation with other monitors of cerebral oxygenation and can be used as a surrogate monitor for cerebral blood flow by measuring the rSO<sub>2</sub>. Rivera-Lara et al studied cerebral autoregulation in 33 comatose patients with TCD and NIRS. They studied the mean velocity index ( $M_x$ ) derived

from TCD and the cerebral oximetry index (CO<sub>x</sub>) derived from NIRS. They concluded that NIRS-derived CO<sub>x</sub> is well correlated and has good agreement with previously validated TCD-based method.(57) Taussky et al. examined the relationship between regional cerebral blood flow (CBF) measurements and NIRS and CT perfusion in a retrospective study. They discovered a statistically significant linear connection between regional CBF on CT perfusion imaging and frontal NIRS-derived cerebral oxygenation measures. (57) Other monitors could be intrusive and complicated to use, but NIRS has proven to be a useful bedside, non-invasive substitute for those.

#### **Effect of Anesthesia induction based on NIRS**

Effect of anaesthesia induction has been previously demonstrated in NIRS based studies. Lovell et al. used functional NIRS (fNIRS) in their study and documented small changes in cerebral oxygenation after induction of anaesthesia with intravenous anaesthetics such as propofol, thiopentone and etomidate.(58) They studied the hemodynamic changes of the patients from baseline till 3 minutes after the administration of the intravenous (IV) induction agents. Changes in oxygenation were reported as differences in the relative oxygenated hemoglobin (HbO<sub>2</sub>) and total hemoglobin concentration (HbTot). The authors found that propofol and thiopental cause an increase in both HbO<sub>2</sub> and HbTot relative to the baseline period. This study revealed that fNIRS was able to measure drug dependent changes in oxygenation associated with anesthetic induction.

Similar study with NIRS was done by Fleck et al. (59) This study was conducted in pediatric population with congenital heart disease. They measured the changes in cerebral oxygenation (by NIRS) and blood supply (by cardiac output

using electrical velocimetry) after Propofol infusion in children with congenital heart disease. Propofol sedation caused a significant drop in mean arterial pressure (MAP) whereas cerebral tissue oxygenation index, showed an increased. The authors postulated that the increase in cerebral oxygenation with propofol sedation despite a decrease in cardiac index and MAP may be due to decreased oxygen consumption of the sedated brain in the presence of an intact cerebral auto-regulation.

In another study, Iwasaki et al. studied the changes in HbO<sub>2</sub> and HbTot which occur after induction with different concentrations of sevoflurane (5%, or 8%) and combination of 67% N<sub>2</sub>O and propofol.(60). The hemodynamic parameters of the patients were continuously recorded from preinduction period until three minutes after airway was secured. The authors found significant increases in HbO<sub>2</sub> and HbTot after 8% sevoflurane induction compared to 5% sevoflurane and propofol. The conclusion was that f NIRS is very sensitive modality to pick up changes caused by different concentrations of even the same anesthetic.

Inspite of the proven beneficial role of NIRS as a monitor of cerebral perfusion and oxygenation, studies on the use of NIRS in AVM surgeries are quite limited. Neurological monitoring with cerebral oximetry can potentially redefine the perioperative management of AVM resections and occlusion procedures. Significant changes in rSO<sub>2</sub> values would alert the treating physician to impaired oxygenation and this would lead to rapid and timely clinical intervention.



## **MATERIAL AND METHODS**

### 3. MATERIAL AND METHODS

The Institute's Institutional Ethics committee (SCT/IEC/1593/December 2020) approved this prospective observational pilot study, and trial registration was done in CTRI prior to patient enrolment (CTRI/2021/02/030915). Written informed consent was obtained from all subjects participating in the trial. We enrolled a total of 15 patients presenting for surgical resection of AVM.

**Inclusion criteria included** - Elective AVM resection surgery, Supratentorial location, Age 18-60 years, GCS of 15, ASA (American Society of Anaesthesiologists) status I and II patients.

**Exclusion criteria included** - Patient refusal, Age less than 18 years and more than 60 years, Patients with GCS <15, Patients presenting for emergency surgery, Patients with recurrent disease, Patients with posterior circulation AVM and ASA (American Society of Anaesthesiologists) status III, IV, V patients, Pregnant & nursing mothers. Patients were recruited from the elective operating list of the neurosurgery department.

**Protocol for Anaesthetic management** - Patients were fasted for 6 hours for solids, 4 hours for liquids and 2 hours for clear fluids. No sedative/opioid premedication was given. Additional details like AVM Spetzler –Martin Grade, size of the nidus, number of feeders and draining veins, whether pre-procedure haemorrhage has occurred and if any previous embolization was done were noted.

#### **Study Protocol**

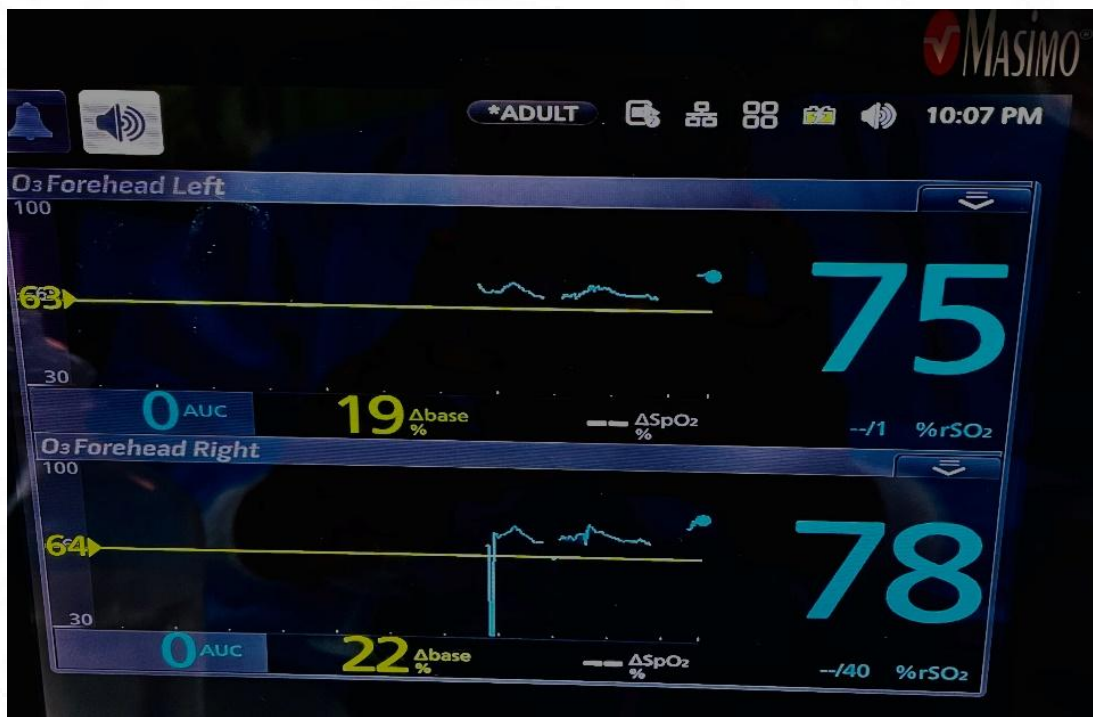
Anaesthesia protocol was standardized for all patients. Standard preinduction monitoring consisted of electrocardiography, pulse oximetry, and non-invasive blood

pressure monitoring. Additionally, patient state index (PSI) sensors and NIRS sensors were placed on the forehead of the patient as per the manufacturer's instructions. Anesthetic induction was done with Fentanyl  $2 \mu\text{g.kg}^{-1}$ , Propofol  $2 \text{mg.kg}^{-1}$ , and Vecuronium  $0.1 \text{mg.kg}^{-1}$ . Post induction invasive arterial monitoring was established in the upper limb radial artery zeroed to the level of the external auditory meatus. End-tidal carbon dioxide (EtCO<sub>2</sub>) and end-tidal anaesthetic gas concentrations were also monitored. After intubation, anaesthesia was maintained using a combination of air: oxygen ratio of 1:1 and sevoflurane titrated to an end-tidal concentration equivalent to 0.7- 1.0 minimum alveolar concentration targeting a patient state index [(PSI)Masimo Root O3 device, California, USA] of 25-30. Patients were ventilated with a tidal volume of  $8-10 \text{ml.kg}^{-1}$ , and the respiratory rate was adjusted to maintain a target EtCO<sub>2</sub> of 35-40 mmHg.

Post excision blood pressure was maintained at baseline, or 20% below the baseline, using sodium nitroprusside (SNP) in titrated doses to achieve a regional cerebral oxygen saturation (rSO<sub>2</sub>) drift of  $< 12\%$  from baseline. (61,62) Patients were transferred to the intensive care unit (ICU) after a computed tomography scan (CT) of the head. The trachea was extubated once the patients were fully awake and obeying commands after reversal with Glycopyrrolate  $10 \mu\text{g.kg}^{-1}$  and Neostigmine  $0.05 \text{mg.kg}^{-1}$ .

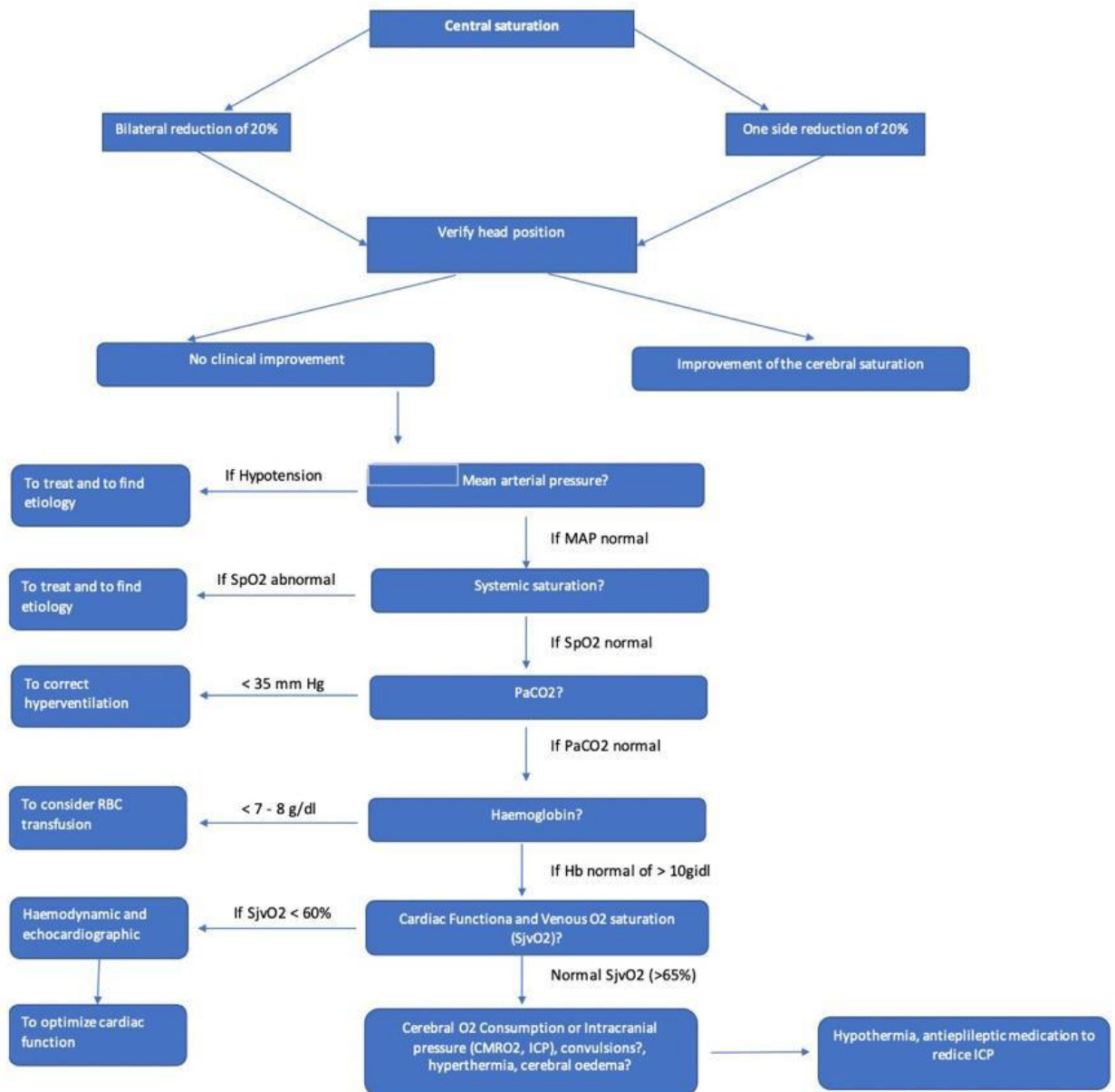
**NIRS monitoring protocol :** NIRS electrodes were placed on the forehead bilaterally as per the manufacturer's instruction (Masimo Root O3 device, California, USA). NIRS readings were taken at various time points (Fig 4). A significant change in NIRS value was defined as a drift or change in NIRS value of 12% from baseline. (62)

1. N1- Baseline NIRS reading taken prior to anaesthesia induction
2. N2- 10 minutes after induction.
3. N3- After arterial occlusion/ligation
4. N4-Post venous occlusion/ligation
5. N5-Post resection of AVM
6. N6- First value in ICU
7. P<sub>1-12</sub>-Hourly in ICU
8. Pc- At the time of complication



**Fig 4. Intraoperative NIRS reading showing bilateral rSO<sub>2</sub> and Δbase which is the percentage drift from the baseline reading.**

Intraoperatively, if an ipsilateral rSO<sub>2</sub> drift > 12% from N<sub>2</sub> was noted, the operative site was evaluated along with optimization of blood pressure, oxygenation, ventilation, haemoglobin, and anaesthesia as per the NIRS algorithm proposed by Trafildo et al.(63)(Fig 5). Postoperatively, any drift in rSO<sub>2</sub>> 12% from N<sub>1</sub> was managed as per the NIRS algorithm (Fig 5), and if the drift persists, an urgent repeat CT scan of the brain would be done. Postoperatively, patients were closely watched for complications such as the new-onset neurological deficit, cerebral infarction or haemorrhage, and seizures. The post-procedure neurological state was assessed using a modified Rankin Score (mRS) at discharge. For analytical purposes, the patients were categorized into two groups, i.e., Group A - patients without complications and Group B - patients who had complications postoperatively



**Fig 5-** NIRS algorithm proposed by Trafidlo et al.  $ScrO_2$  – local saturation of the cerebral cortex; MAP – mean arterial pressure;  $SaO_2$  – oxygen saturation of arterial blood; Hb – haemoglobin; CO – cardiac output;  $ScvO_2$  – central venous oxygen saturation,  $CMRO_2$  – cerebral metabolic rate of oxygen; ICP – intracranial pressure

## **STATISTICAL ANALYSIS**

This was an observational pilot study. However, based on previous literature and the average annual admission of patients with cerebral AVM in the neurosurgery department, using an alpha error of 5% and power of 80%, a sample size of 14 was determined. Descriptive data were expressed as a percentage (%) for categorical variables and Mean  $\pm$  Standard Deviation (SD) for continuous variables. In addition, an unpaired t-test was done to determine the inter-group p-value between groups A and B. Repeated measures ANOVA test was done to determine intragroup p value and significance over time. Mann-Whitney test was done to compare mean NIRS drift between groups A and B as the data was not normally distributed. All statistical analyses were performed by the SPSS software (Version 26.0, IBM Corporation, New York, USA). A p-value  $<0.05$  was considered statistically significant.



**RESULTS**

## 4. RESULTS

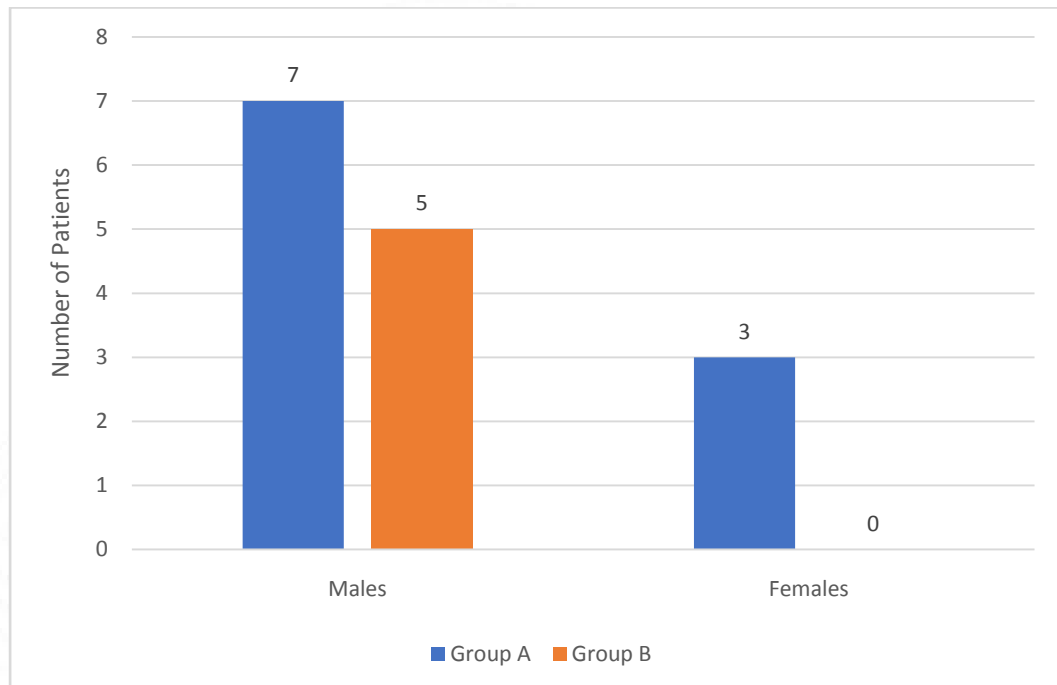
A total of 15 cases posted for surgical excision of cerebral AVM were enrolled in the study. Out of these, five patients developed complications postoperatively, and ten patients did not develop any complications postoperatively. These were the study groups used for data comparison, i.e., Group A - Patients without complications and Group B - Patients who had complications postoperatively.

### 1. Demographic data

**Table 1: Demographic details of study groups**

Parameters	Group A (n=10)	Group B (n=5)	p-value
Mean age (years) [Mean±SD]	23.5 ± 8.51	35.4 ± 14.39	<b>0.03*</b>
Median age (years)	20.5	27	-
Minimum age (years)	17	19	-
Maximum age (years)	45	55	-
Number of males(n)	7	5	0.49 <sup>#</sup>
Number of females(n)	3	0	
Preoperative Hemoglobin (g/dl) [Mean±SD]	14.16 ± 2.26	13.64 ± 2.41	0.68

p<0.05 considered significant by unpaired t-test\* or chi-square test<sup>#</sup>



**Fig 6: Gender distribution in study groups**

In table 1, age and gender details of the patients are mentioned. It was noted that the mean age in group B was significantly higher compared to those in group A [ $35.4 \pm 14.39$  vs  $23.5 \pm 8.5$ , ( $p$  value=0.03)]. The gender distribution in both study groups were comparable ( $p=0.49$ ), but none of the patients in group B was females (Table 1, Fig 6). The mean pre-operative haemoglobin in group A was comparable to that in group B [ $14.16 \pm 2.26$  vs  $13.64 \pm 2.41$  g/dl, ( $p=0.68$ )](Table 1).

## 2. AVM characteristics

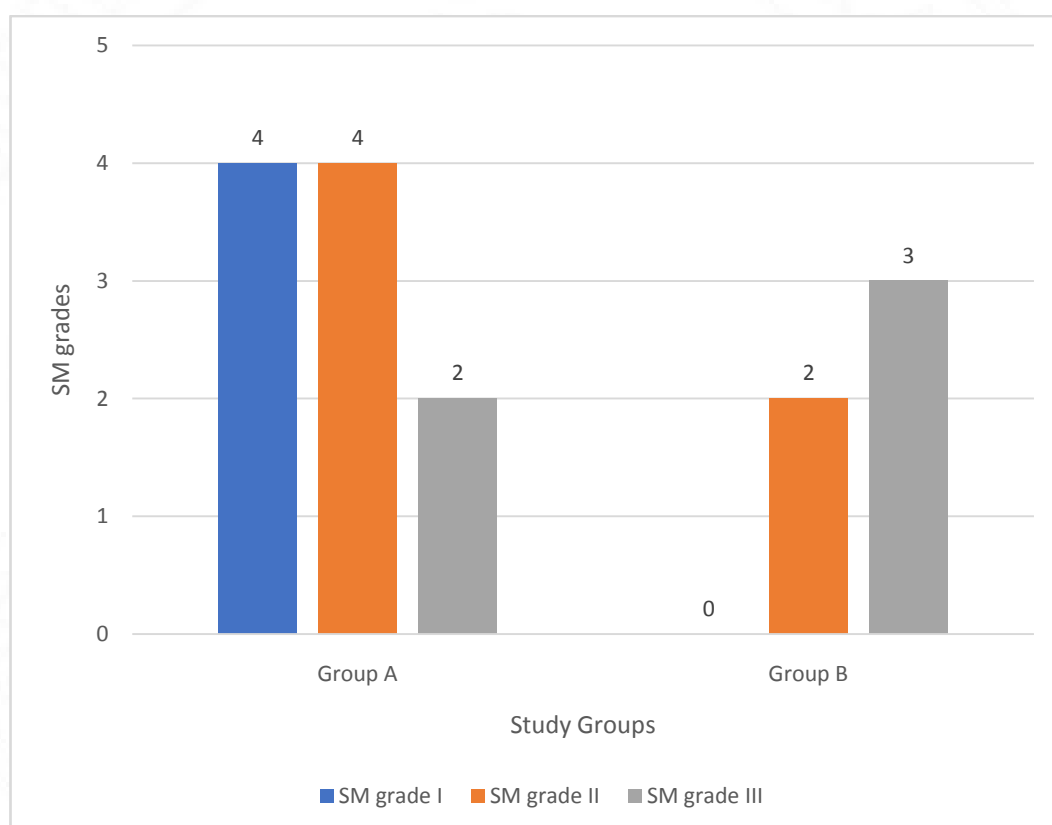
**Table 2 – AVM Characteristics in the study population**

<b>AVM Characteristics</b>	<b>Number (Percentage %)</b>
<b>Spetzler Martin grade (SM grade)</b>	
I	4(26.6%)
II	8(53.3%)
III	3(21.4%)
IV	0(0%)
V	0(0%)
<b>Location of AVM</b>	
Frontal	3(21.4%)
Temporal	1(7.1%)
Frontotemporal	2(14.2%)
Insula	2(14.2%)
Parietal	7(46.6%)
<b>Clinical Presentation</b>	
Headache	4(26.6%)
Seizures	6(42.8%)
Haemorrhage	5(35.7%)

None of our patients had undergone preoperative embolization. Majority of the AVMs were located in the parietal lobe (46.6%), followed by frontal (21.4%), followed by frontotemporal and insula (14.2 % each) and least in temporal lobe (7.1%)(Table 2). In clinical presentation, majority of our patients had presented with

seizures (42.8%), followed by hemorrhage (35.7%) and followed by headache(26.6%) (Table 2).

In regard to AVM SM grades, the majority of the patients had SM grade II AVMs (53.3%), followed by SM grade I (26.6%) and SM grade II AVMs (21.4%). None of the patients in our study had an SM grade IV and V AVMs (Table 2). In Group B, 60% were SM grade III AVMs, followed by SM grade II AVMs (40%) and no SM grade I AVM. While in Group A, 40% were SM grade I and II AVMs, and only 20% were SM grade III AVMs (Fig 7).



**Fig 7: Spetzler-Martin AVM grading in study groups**

### 3. Data evaluation of Hemodynamic variables.

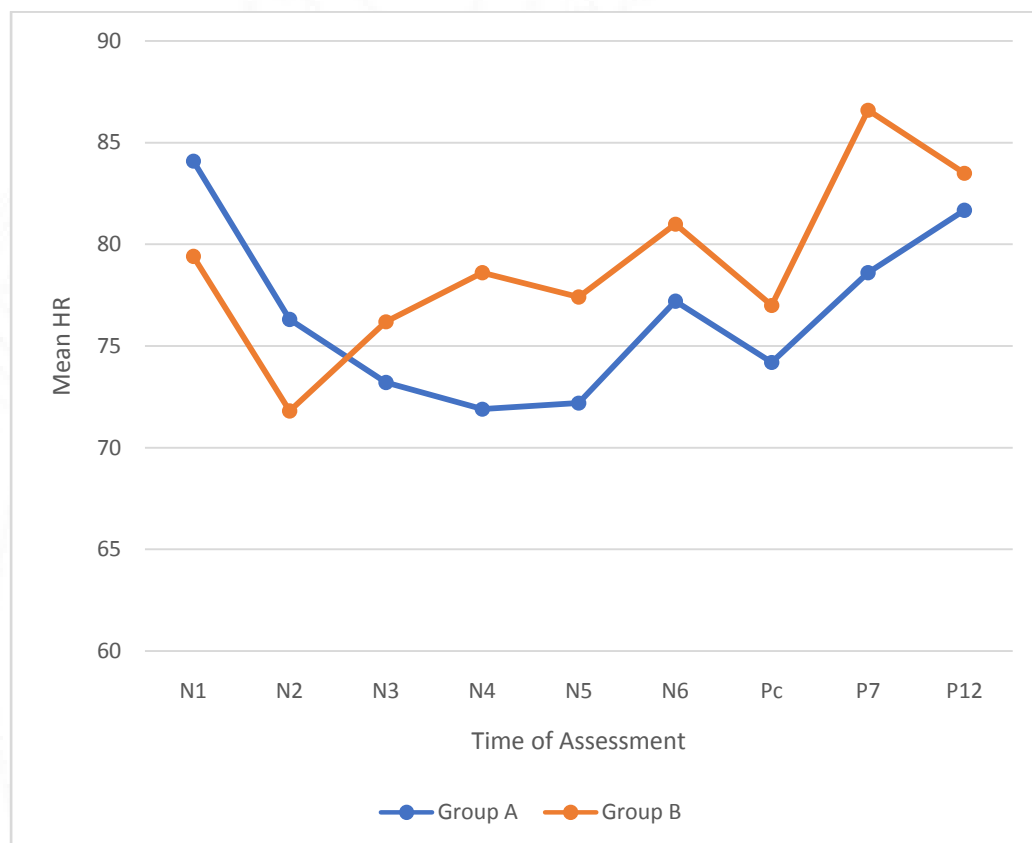
**Table 3- Mean change in Heart Rate (HR) across time points in the study groups**

The time point of assessment	Mean HR in Group A (Beats/minute)	Mean HR in Group B (Beats/minute)	p-value (intergroup)
<b>N1</b>	84.1 ± 9.99	79.4 ± 19.44	0.45
<b>N2</b>	76.3 ± 17.07	71.8 ± 14.81	0.53
<b>N3</b>	73.2 ± 11.26	76.2 ± 16.16	0.48
<b>N4</b>	71.9 ± 14.81	78.6 ± 14.64	0.17
<b>N5</b>	72.2 ± 12.59	77.4 ± 12.54	0.29
<b>N6</b>	77.2 ± 12.75	81 ± 5.79	0.38
<b>Pc</b>	74.2 ± 10.92	77 ± 13.42	0.41
<b>P7</b>	78.6 ± 7.46	86.6 ± 13.03	0.07
<b>P12</b>	81.67 ± 14.36	83.5 ± 3.54	0.06
<b>p value (intragroup)</b>	0.08	<b>0.03*</b>	

Intragroup p-value calculated by repeated measures ANOVA, intergroup p-value calculated by unpaired t-test,\* p<0.05 considered significant

The mean HR was statistically comparable between the study groups across all time points including baseline (p >0.05)(Table 3). However, there was a

significant increase in HR over time in Group B in the post operative phase ( $p=0.03$ ), while in group A the change over time in HR was not significant statistically ( $p=0.08$ ) (Table 3, Fig 8).



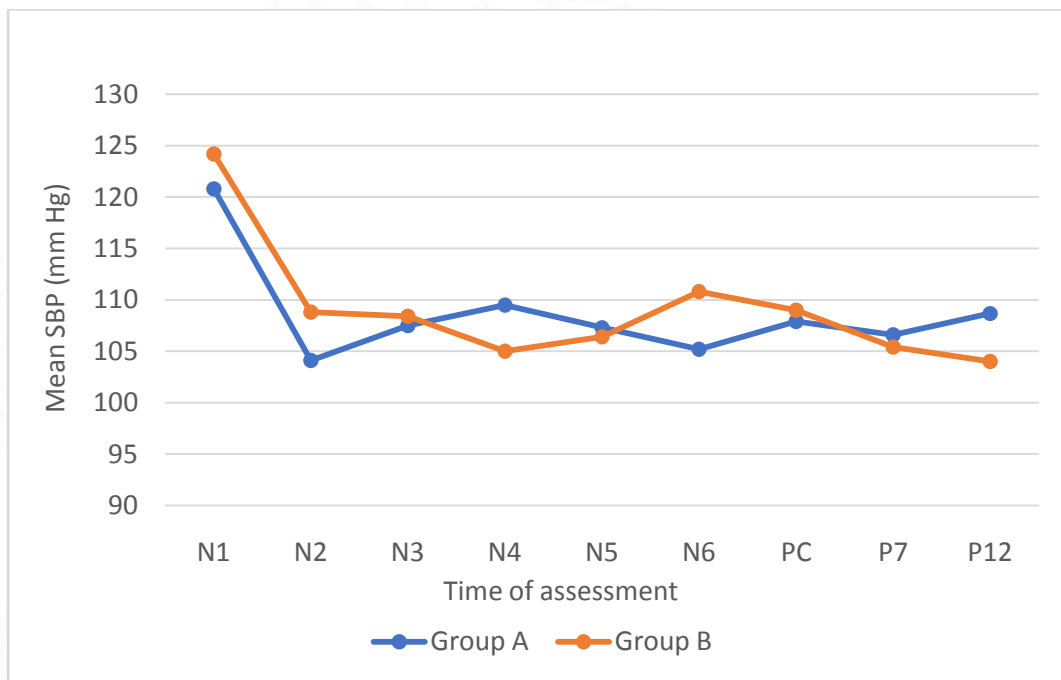
**Fig 8: Mean change in Heart Rate across time points in study groups**

**Table 4 - Mean change in Systolic blood pressure (SBP) across time points in study groups**

The time point of assessment	Mean SBP in Group A (mm Hg)	Mean SBP in Group B (mm Hg)	p-value (intergroup)
N1	120.8 ± 15.55	124.2 ± 17.92	0.61
N2	104.1 ± 8.9	108.8 ± 15.8	0.28
N3	107.5 ± 10.71	108.4 ± 11.26	0.73
N4	109.5 ± 6.9	105 ± 10.05	0.37
N5	107.3 ± 10.76	106.4 ± 13.79	0.78
N6	105.2 ± 9.89	110.8 ± 11.65	0.29
Pc	107.9 ± 5.43	109 ± 8.63	0.48
P7	106.6 ± 5.78	105.4 ± 8.93	0.72
P12	108.67 ± 10.02	104 ± 5.66	0.27
<b>p-value (intragroup)</b>	<b>0.03*</b>	<b>0.01*</b>	

Intragroup p-value calculated by repeated measures ANOVA, intergroup p-value calculated by unpaired t-test, \*p<0.05 considered significant.

The mean SBP was statistically comparable between both the study groups at all the time points including baseline ( $p>0.05$ )(Table 4). However, the intragroup assessment showed a significant decrease in SBP over time in both the study groups ( $p=0.03$ ,  $p=0.01$ )(Table 4, Fig 9).



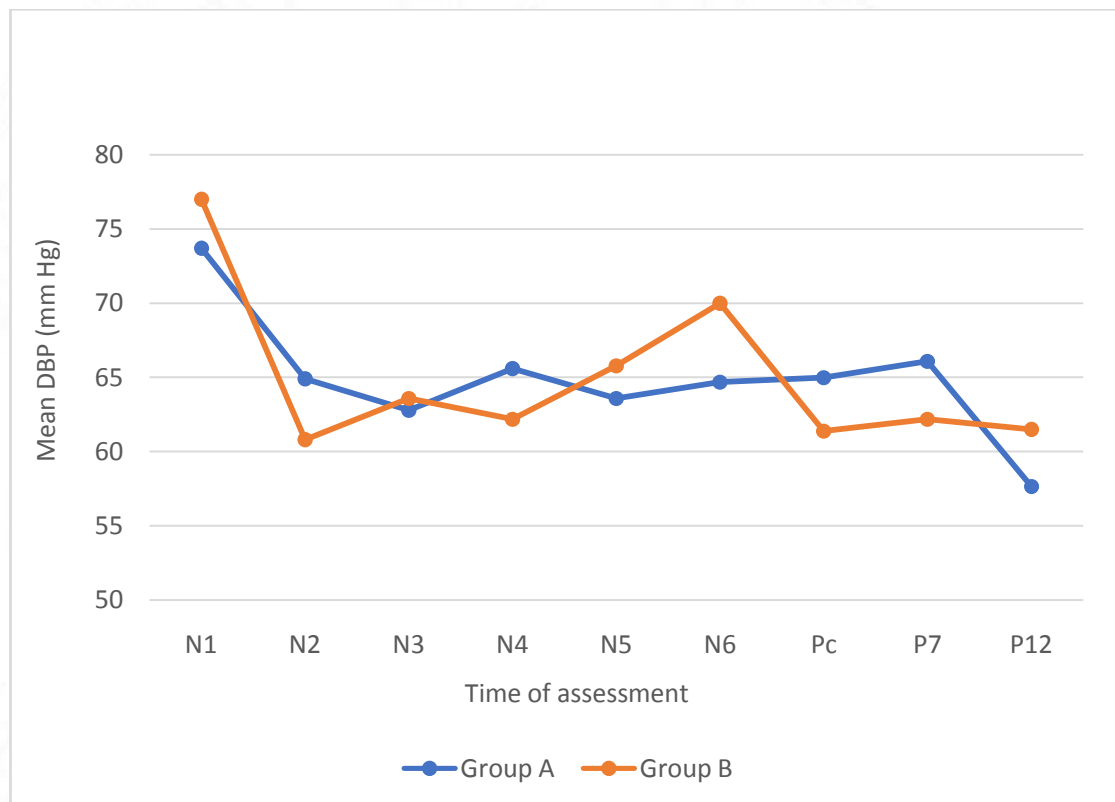
**Fig 9: Mean change in Systolic blood pressure across time points in study groups**

**Table 5- Mean change in Diastolic Blood Pressure (DBP) across time points in study groups**

The time point of assessment	Mean DBP in Group A (mm Hg)	Mean DBP in Group B (mm Hg)	p-value (intergroup)
N1	73.7 ± 8.41	77 ± 15.52	0.47
N2	64.9 ± 11.03	60.8 ± 12.01	0.57
N3	62.8 ± 13.69	63.6 ± 7.57	0.79
N4	65.6 ± 7.66	62.2 ± 5.67	0.66
N5	63.6 ± 9.49	65.8 ± 10.5	0.62
N6	64.7 ± 14.02	70 ± 4.18	0.29
Pc	65 ± 10.32	61.4 ± 10.14	0.09
P7	66.1 ± 9.8	62.2 ± 5.89	0.22
P12	57.67 ± 8.62	61.5 ± 3.54	0.17
<b>p-value (intragroup)</b>	<b>0.03*</b>	<b>0.01*</b>	

Intragroup p-value calculated by repeated measures ANOVA, intergroup p-value calculated by unpaired t-test in DBP, \*p<0.05 considered significant

The mean DBP was statistically comparable between the study groups at all the time points, including baseline (p>0.05) (Table 5). However, the intragroup assessment showed a significant decrease in DBP over time post excision and postoperatively in both the study groups (p=0.03, p=0.01) (Table 5, Fig 10).



**Fig 10: Mean change in Diastolic Blood Pressure across time points in study groups**

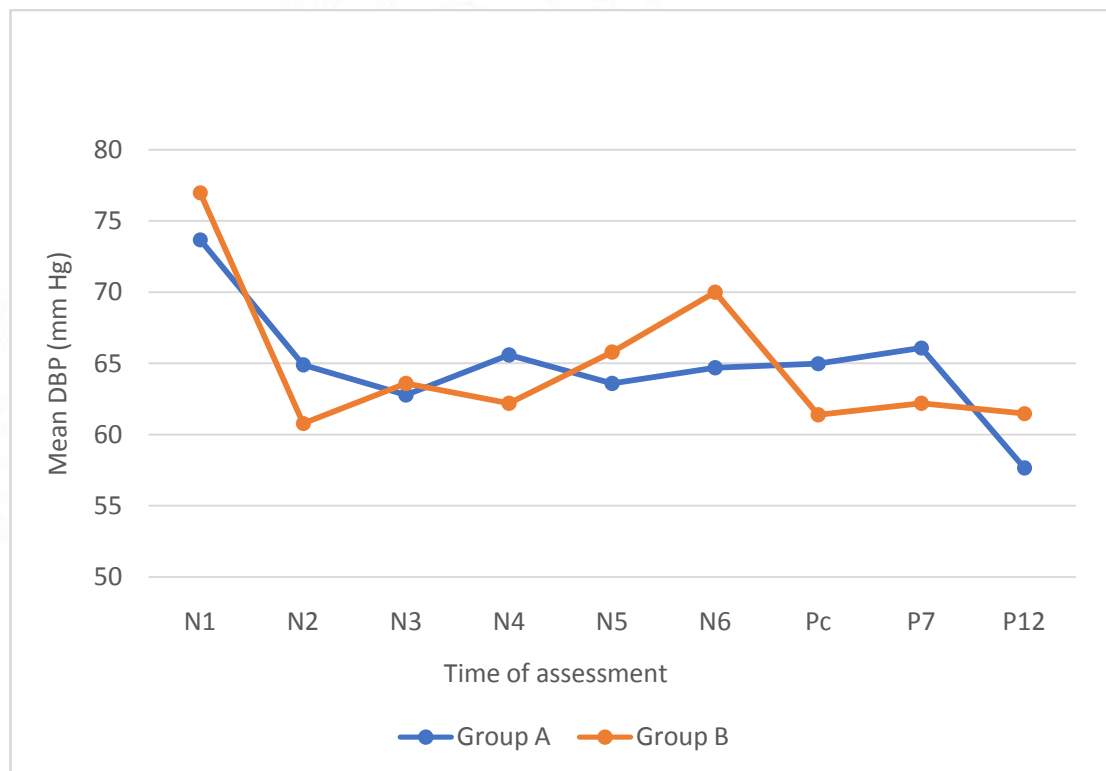
**Table 6- Mean change in Mean Arterial Pressure (MAP) across time points in study groups**

The time point of assessment	Mean MAP in Group A (mm Hg)	Mean MAP in Group B (mm Hg)	p-value (intergroup)
N1	88.5 ± 7.85	87.6 ± 15.71	0.59
N2	77.7 ± 10.22	74.4 ± 12.62	0.36
N3	78.5 ± 11.86	79.6 ± 8.79	0.78
N4	82.1 ± 7.58	78.4 ± 7.5	0.31
N5	68.4 ± 2.07	80.1 ± 8.72	<b>0.01*</b>
N6	79.9 ± 11.52	78.2 ± 7.26	0.72
Pc	75 ± 5.48	78.4 ± 5.41	0.37
P7	76.9 ± 8.03	73.4 ± 5.32	0.43
P12	74 ± 7.81	67 ± 0	0.08
<b>p-value (intragroup)</b>	0.18	<b>0.03*</b>	

Intragroup p-value calculated by repeated measures ANOVA, intergroup p-value calculated by unpaired t-test, \* p<0.05 considered significant

The mean MAP was statistically comparable between the study groups at baseline and at all the time points except at N5 time point (i.e. post excision), when it was significantly higher in group B as compared to group A [68.4 ± 2.07 vs 80.1 ± 8.72, (p=0.01)](Table 6). On intragroup assessment, a significant change in MAP was noted over time in Group B (p=0.03). It was noted that the MAP significantly decreased over time post operatively in Group B as compared to Group A (p =0.03).

However, the change in MAP over time in group A was not statistically significant ( $p=0.18$ )(Table 6, Fig 11).



**Fig 11- Mean change in Mean Arterial Pressure across time points in study groups**

#### 4. Data evaluation of regional cerebral oxygen saturation (rSO<sub>2</sub>)

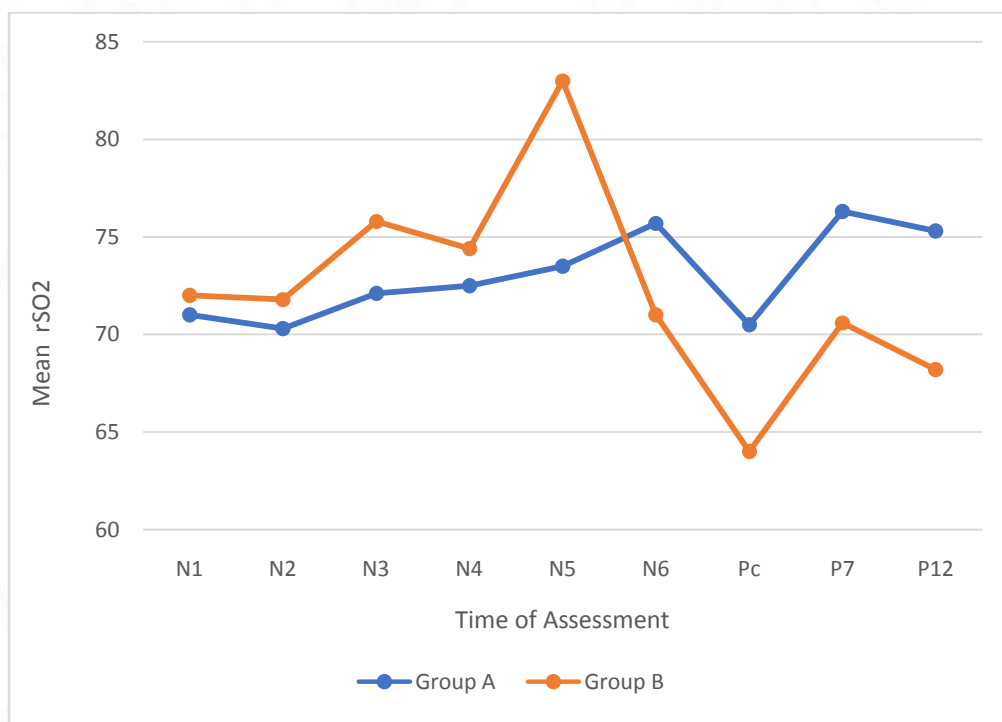
**Table 7- Mean ipsilateral regional cerebral oxygen saturation (rSO<sub>2</sub>) across time points in study groups**

The time point of assessment	rSO <sub>2</sub> in Group A patients(%)	rSO <sub>2</sub> in Group B patients(%)	p-value (intergroup)
<b>N1</b>	71 ± 7.96	72 ± 7.68	0.82
<b>N2</b>	70.3 ± 8.63	71.8 ± 8.76	0.75
<b>N3</b>	72.1 ± 7.71	75.8 ± 7.92	0.18
<b>N4</b>	72.5 ± 6.13	74.4 ± 7.5	0.49
<b>N5</b>	73.5 ± 7.07	83 ± 6.08	<b>&lt;0.01*</b>
<b>N6</b>	75.7 ± 7.09	71 ± 6.04	0.17
<b>Pc</b>	70.5 ± 7.17	64 ± 9.33	<b>0.04*</b>
<b>P7</b>	76.3 ± 8.04	70.6 ± 9.2	0.09
<b>P12</b>	75.3 ± 5.35	68.2 ± 10.2	<b>0.02*</b>
<b>p-value (intragroup)</b>	0.17	<b>&lt;0.01*</b>	

Intragroup p-value calculated by repeated measures ANOVA, intergroup p-value calculated by unpaired t-test, \*p<0.05 considered significant.

The ipsilateral mean rSO<sub>2</sub> was noted to be significantly higher in Group B at N5 time point (i.e. post-AVM excision) as compared to Group A [ 83 ± 6.08% vs 73.5 ± 7.07%, (p<0.01)](Table 7). However at the time of complication (i.e Pc time point), the ipsilateral mean rSO<sub>2</sub> was significantly lower in Group B than in Group A

[ $64 \pm 9.33\%$  vs  $70.5 \pm 7.17\%$ , ( $p=0.04$ )]. Similarly, Group B patients had a significantly lower mean  $rSO_2$  at P12 time point as compared to Group A [ $68.2 \pm 10.2$  vs  $75.3 \pm 5.35$ , ( $p=0.02$ )](Table 7, Fig 12). On intragroup assessment, a significant change in the ipsilateral mean  $rSO_2$  over time was noted in the group B ( $p<0.01$ ) in comparison to Group A where it was statistically not significant ( $p=0.17$ )(Fig 12).



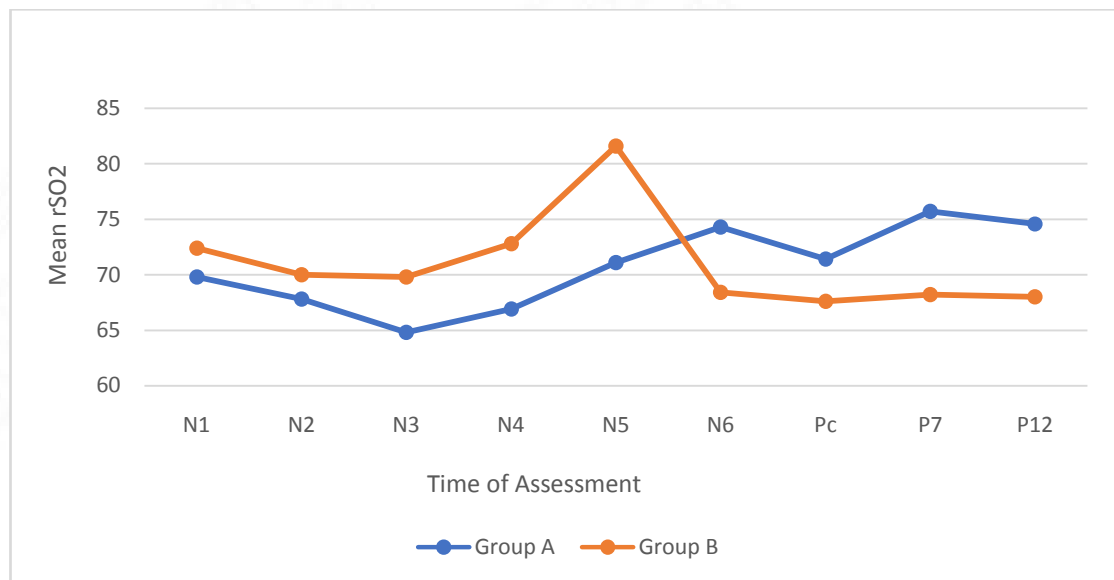
**Fig 12- Change in mean ipsilateral regional cerebral oxygen saturation ( $rSO_2$ ) over time**

**Table 8- Mean contralateral regional cerebral oxygen saturation (rSO<sub>2</sub>) across time points in study groups**

Time point of assessment	Mean rSO <sub>2</sub> in Group A (%)	Mean rSO <sub>2</sub> in Group B (%)	p-value (intergroup)
N1	69.8 ± 6.68	72.4 ± 6.8	0.49
N2	67.8 ± 8.34	70 ± 7.84	0.38
N3	64.8 ± 5.01	69.8 ± 8.01	0.15
N4	66.9 ± 5.28	72.8 ± 8.58	0.08
N5	71.1 ± 6.98	81.6 ± 9.53	<b>0.02*</b>
N6	74.3 ± 6.95	68.4 ± 5.03	0.21
Pc	71.4 ± 4.92	67.6 ± 3.84	0.24
P7	75.7 ± 10.01	68.2 ± 4.02	0.25
P12	74.67 ± 6.65	68 ± 3.31	0.28
<b>p value (intragroup)</b>	0.14	<b>0.02*</b>	

Intragroup p-value calculated by repeated measures ANOVA, intergroup p-value calculated by unpaired t-test, p<0.05 considered significant.

The contralateral mean rSO<sub>2</sub> was comparable between the two groups except at N5 time point; wherein there was a significantly higher mean rSO<sub>2</sub> in Group B as compared to Group A [81.6 ± 9.53% vs 71.1 ± 6.98%, (p=0.02)](Table 8). On intragroup assessment, a significant change over time in mean rSO<sub>2</sub> was noted in Group B (p=0.02). However, group A's change over time in mean rSO<sub>2</sub> was statistically insignificant (p=0.14) (Table 8, Fig 13).



**Fig 13: Change in mean contralateral regional cerebral oxygen saturation(rSO<sub>2</sub>) over time**

**Table 9- Drift of Ipsilateral rSO<sub>2</sub> values at N5 (post excision) from N2 (post-induction) in individual patients**

Patient. No.	rSO <sub>2</sub> at N5	rSO <sub>2</sub> at N2	Drift %
<b>Group A</b>			
<b>1</b>	71	64	10.94%
<b>2</b>	65	60	8.33%
<b>3</b>	74	70	5.71%
<b>4</b>	71	73	-2.82%
<b>5</b>	90	86	4.65%
<b>6</b>	73	76	-4.11%
<b>7</b>	64	59	8.47%
<b>8</b>	73	68	7.35%
<b>9</b>	70	75	-7.14%
<b>10</b>	74	82	-9.76%
<b>Group B</b>			
<b>1</b>	82	88	-6.82%
<b>2</b>	82	72	<b>13.89%</b>
<b>3</b>	90	81	<b>12.11%</b>
<b>4</b>	87	77	<b>12.98%</b>
<b>5</b>	74	65	<b>13.85%</b>

None of the patients in group A had an ipsilateral mean rSO<sub>2</sub> drift of >12% post excision of AVM, with the maximum mean rSO<sub>2</sub> drift being 10.94%. In group B however, four among the five patients (80%) had an ipsilateral mean rSO<sub>2</sub> drift of >12%, the highest being a drift of 13.89% (Table 9).

**Table 10- Drift of Ipsilateral rSO<sub>2</sub> values at N6 (First value in ICU) from N1(Baseline) in individual patients**

Patient.No.	rSO <sub>2</sub> at N6	rSO <sub>2</sub> at N1	Drift %
<b>Group A</b>			
1	68	66	3.03%
2	70	66	5.7%
3	73	68	7.35%
4	87	86	1.16%
5	87	78	11.54%
6	76	71	7.04%
7	69	61	<b>12.11%</b>
8	77	72	6.94%
9	70	67	4.48%
10	80	79	1.27%
<b>Group B</b>			
1	80	72	11.11%
2	72	85	<b>-15.29%</b>
3	73	88	<b>-17.04%</b>
4	73	84	<b>-13.09%</b>
5	67	82	<b>-18.29%</b>

One patient in group A (10% cases) had an ipsilateral mean rSO<sub>2</sub> drift of >12% at N6 from N1 (i.e 12.11%)(Table 10). However, four among the five patients (80%) in group B had an ipsilateral mean rSO<sub>2</sub> drift of >12% at N6 from N1, and the highest mean rSO<sub>2</sub> drift being 18.29% (Table 10).

**Table 11- Comparison of mean drift (%) in the ipsilateral and contralateral rSO<sub>2</sub> between study groups.**

Parameter assessed	Group A	Group B	p-value
Mean ipsilateral rSO <sub>2</sub> Drift (at N5 from N2)	4.98 ± 5.7 %	12.01 ± 2.63 %	<b>0.022*</b>
Mean Ipsilateral rSO <sub>2</sub> Drift (at N6 from N1)	6.88 ± 4.5 %	-14.96 ± 0.080 %	<b>&lt;0.01*</b>
Mean contralateral rSO <sub>2</sub> Drift (at N5 from N2)	5.24 ± 5.38 %	5.16 ± 7.99 %	0.57
Mean contralateral rSO <sub>2</sub> Drift (at N6 from N1)	6.71 ± 8.18 %	-12.34 ± 8.87 %	<b>&lt;0.01*</b>

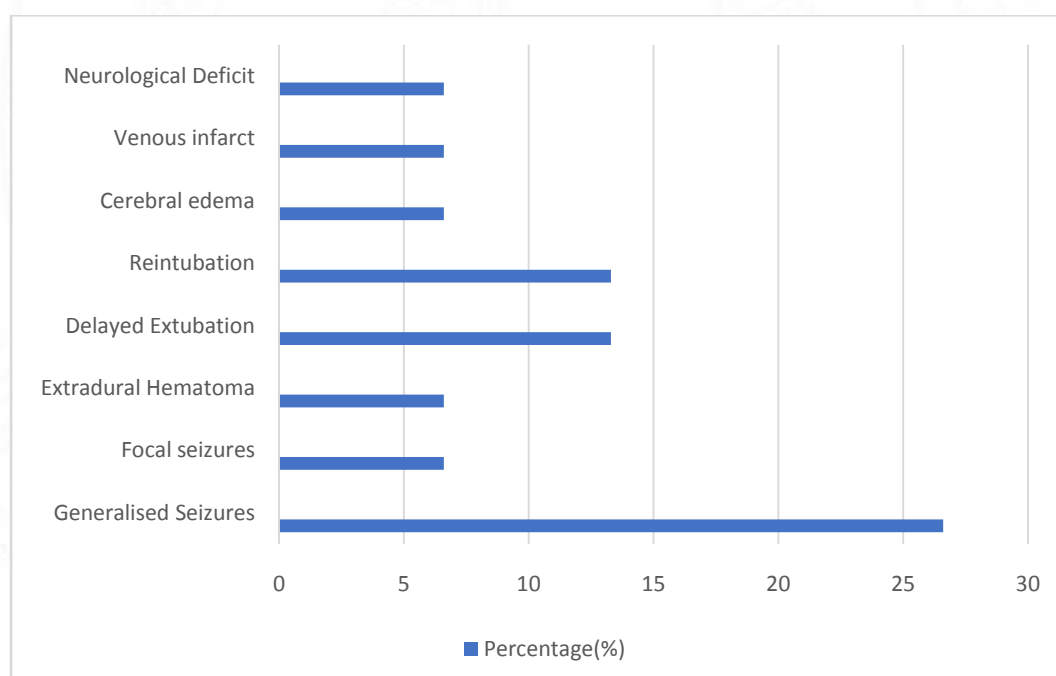
\*P<0.05 considered significant by Mann Whitney test

The mean rSO<sub>2</sub> drift from N2 to N5, i.e. post excision on the ipsilateral side, was statistically significant in group B compared to group A [12.01 ± 2.63 % vs 4.98 ± 5.7 % (p-value 0.022)](Table 11). On the contralateral side, however, the mean rSO<sub>2</sub> drift was insignificant between both groups post excision. Postoperatively, in group B, the mean ipsilateral rSO<sub>2</sub> drift from N1 to N6 was statistically significant compared to group A [14.96 ± 0.080 % vs 6.88 ± 4.5 % (p-value <0.01)](Table 11). On the contralateral side also, the mean rSO<sub>2</sub> drift from N1 to N6 was statistically significant in group B compared to A [12.34 ± 8.87 % vs 6.71 ± 8.18%, p value<0.01].

### 5. *Data evaluation of intraoperative blood loss, use of vasopressors and fluid requirements.*

The intraoperative blood loss was less than 500 ml in 11 patients. Three patients in group B (60%) had blood loss >1000 ml and required blood transfusions ranging from 235 ml to 500 ml (Mean:  $348 \pm 138.95$  ml). The intra-operative fluid requirement in group B was significantly higher than in group A [ $3.09 \pm 0.36$  versus  $2.55 \pm 0.24$  litres, ( $p < 0.05$ )]. None of the patients required inotropic support perioperatively. None of the patients had hypertensive surges nor required inotropic support in the perioperative period. All patients were started on sodium nitroprusside infusion post excision, and the average requirement in Group A was 150 mg and 285 mg in group B ( $p$  value= 0.0018).

### 6. *Data evaluation of post-operative complications*



**Fig 14- Incidence of postoperative complications**

In total, five among the fifteen patients developed postoperative complications (33.3%). The etiology and clinical events encountered in Group B patients are elaborated in Table 12.

**Table 12: The etiology and clinical events in patients in Group B patients**

Patient Numbers	Etiopathology	Clinical Events
Patient 1	Residual AVM	Seizures, Reintubation
Patient 2	Cerebral oedema	Delayed Awakening, Seizures
Patient 3	Extradural hematoma	Focal Seizures
Patient 4	Venous Infarct	Seizure, Delayed Awakening, Postoperative neurological deficit
Patient 5	Residual AVM	Seizures, Reintubation

All the patients had seizure semiology in the postoperative period. Generalised seizures were seen in four (26.6%) patients. One patient developed an ipsilateral EDH and had one episode of focal seizures (6.6%) (Fig 14). One patient had global cerebral oedema on postoperative CT with two episodes of seizures and was extubated after 24 hours (6.6%) (Fig 14). One patient had an ipsilateral venous infarct postoperatively on CT and was electively ventilated for 24 hours before extubation. This patient had developed a new onset focal neurological deficit (6.6%). Two patients were reintubated due to recurrent seizures (13.3%) (Fig 14). Two patients (13.3%) had residual AVMs in the post-operative angiogram.

### **7. Data evaluation of postoperative outcome**

The mean duration of ICU stay was significantly higher in group B ( $51 \pm 22.10$  hours) as compared to patients in group A ( $17 \pm 6.12$  hours) ( $p=0.028$ ). All patients were discharged with mRS score of  $<2$  except the two patients who developed venous infarct (mRS 4) and global cerebral oedema (mRS 3). There was zero case fatality in our study population.

### ***Summary of Significant findings in our study:***

#### **I) Demographic data and AVM Characteristics**

1. Five patients developed postoperative complications (33.3%) and were included in Group B.
2. Group B had a higher mean age as compared to group A [ $35.4 \pm 14.39$  vs  $23.5 \pm 8.51$ , ( $p= 0.03$ )].
3. Gender bias was skewed in favour of the male gender in group B as there were no females in this group.
4. In Group B, the majority (60%) were SM grade III, followed by SM grade II (40%) and no SM grade I AVMs in Group B.
5. In Group A, 40% were grade I and II AVMs, and only 20% were SM grade III AVMs.

#### **II) Hemodynamic variables**

1. The mean HR, SBP and DBP were statistically comparable between the study groups across all time points( $p$  value $>0.05$ ).

2. There was a significant increase in HR over time in Group B in the postoperative phase ( $p=0.03$ ), while in Group A the change over time was not significant statistically( $p=0.08$ ).
3. There was a significant decrease in SBP and DBP over time in Group B in excision and postoperative phase ( $p=0.01$ ), while in Group A the change over time was not significant statistically.
4. MAP was significantly higher in Group B at the N5 time point as compared to Group A [ $68.4 \pm 2.07$  vs  $80.1 \pm 8.72$ , ( $p = 0.01$ )].
5. On intragroup assessment, a significant change over time in MAP was noted in Group B as compared to Group A ( $p$  value= $0.03$  vs  $0.18$ ).

### **III) Regional cerebral oxygen saturation( $rSO_2$ )-**

#### **A) Ipsilateral side**

- a) The ipsilateral mean  $rSO_2$  was significantly higher in Group B at N5 time point compared to Group A (post excision) [ $83 \pm 6.08$  vs  $73.5 \pm 7.07$ , ( $p < 0.01$ )].
- b) The ipsilateral mean  $rSO_2$  at the time of complication (Pc) was significantly lower in Group B as compared to group A [ $64 \pm 9.33$  vs  $70.5 \pm 7.17$ , ( $p=0.04$ )].
- c) The ipsilateral mean  $rSO_2$  at 12 hours postoperatively (P12) was significantly lower in Group B [ $68.2 \pm 10.2$  vs  $75.3 \pm 5.35$ , ( $p=0.02$ )].
- d) Also, a significant change over time in mean ipsilateral  $rSO_2$  was noted in Group B ( $p$  value $<0.01$ ) while in Group A the change in mean  $rSO_2$  over time was not significant statistically ( $p < 0.17$ ).

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**B) Contralateral side**

- a) The contralateral mean rSO<sub>2</sub> was significantly higher in Group B at the N5 time point (post excision), as compared to Group A [81.6 ± 9.53 vs 71.1 ± 6.98, (p value=0.02)].
- b) Also, a significant change over time in contralateral mean rSO<sub>2</sub> was noted in Group B (p =0.02), while the change over time in mean rSO<sub>2</sub> was not significant statistically in Group A (p value =0.14)

**C) Drifts in rSO<sub>2</sub>**

- a) The mean ipsilateral rSO<sub>2</sub> drift from N2- N5 (i.e post excision) was significantly higher in Group B as compared to Group A [(12.01 ± 2.63 % vs 4.98 ± 5.7%, (p-value 0.02)]
- b) The mean ipsilateral rSO<sub>2</sub> drift from N1-N6 (i.e postoperatively) was significantly lower in Group B as compared to Group A [14.96 ± 0.080 % vs 6.88 ± 4.5 %, (p-value <0.01)].
- c) None of the patients in Group A had an ipsilateral rSO<sub>2</sub> drift of >12% post excision with the maximum drift being 10.94%. In Group B, four of the five patients (80%) had an ipsilateral post excision rSO<sub>2</sub> drift of >12%.
- d) Only one patient in Group A had an ipsilateral rSO<sub>2</sub> drift >12% (12.11%) postoperatively. In Group B, four of the five patients (80%) had an ipsilateral postoperative rSO<sub>2</sub> drift of >12%.

#### **IV) Blood loss and Intraoperative fluid**

1. The intraoperative blood loss was less than 500 ml in 11 patients.
2. Three patients in group B (60%) had blood loss >1000 ml and required blood transfusions ranging from 235 ml to 500 ml (Mean:  $348 \pm 138.95$  ml).
3. The intra-operative fluid requirement in group B was significantly higher than in group A [ $(3.09 \pm 0.36$  versus  $2.55 \pm 0.24$  litres,  $p < 0.05$ ).
4. None of the patients required ionotropic support perioperatively.
5. None of the patients had hypertensive surges nor required ionotropic support in the perioperative period.
6. All patients were started on sodium nitroprusside infusion post excision, and the average requirement in Group A was 150 mg and 285 mg in group B (p value = 0.0018).

#### **V) Postoperative complications and postoperative outcome**

1. All the patients had seizure semiology in the postoperative period.
2. Generalised seizures were seen in four (26.6%) patients.
3. One patient developed an ipsilateral EDH and had one episode of focal seizures (6.6%).
4. One patient had global cerebral oedema with two episodes of seizures and was extubated after 24 hours (6.6%).
5. One patient had an ipsilateral venous infarct postoperatively and was electively ventilated for 24 hours before extubation. This patient had developed a new onset focal neurological deficit (6.6%).

6. Two patients were reintubated due to recurrent seizures (13.3%).  
Two patients (13.3%) had residual AVMs in the post-operative angiogram.
7. Mean ICU stay duration was significantly higher in group B as compared to group A p-value [ $51 \pm 22.10$  hours vs  $17 \pm 6.12$  hours (p-value 0.02).
8. The intra-operative fluid requirement in group B was significantly higher than in group A ( $3.09 \pm 0.36$  versus  $2.55 \pm 0.24$  litres,  $p < 0.05$ )
9. All patients were discharged with mRS score  $< 2$ , except the patient with venous infarct with mRS score = 4 and patient with global cerebral oedema with mRS = 3.



**DISCUSSION**

## 5. DISCUSSION

In our study, most patients were aged 16-20 years (35.7%). However, the mean age in group B was significantly higher ( $p=0.03$ ) as compared to those in the group A. Though the gender distribution in both study groups was comparable ( $p=0.49$ ), none of the patients in group B was females, indicating a male preponderance for complications in this study. The average age of presentation has been reported as 20–45 years, with a peak occurrence in the fourth decade, even though literature reveals no gender preponderance. (64,65) All our patients had solitary AVMs, consistent with current literature postulating that only 2% of AVMs are multiple. (64) While the literature indicates that intracranial bleed and seizures are the most frequent presentations of AVMs, the majority of our patients (42.8%) presented with seizures, followed by hemorrhage (35.7%) and headache (26.6 % ). (9) Patients in Group B had AVMs with a higher SM grade than patients in Group A, which was consistent with the results of earlier outcome studies on cerebral AVMs, which found that patients with a higher SM grade had a higher incidence of problems. (52)

Even though there was no significant difference in the HR, SBP and DBP between the two groups, intragroup analysis of haemodynamic variables of patients in Group B showed a significantly higher heart rate with a significant concomitant decrease in SBP and DBP over time postoperatively. Moreover, the mean arterial blood pressure was comparable between the two groups across all time points except during the immediate post-excision period (N5), wherein there was a significantly higher MAP in group B ( $p=0.01$ ). However, the patients in group A only had a

significant drop in SBP and DBP without significant HR changes in the post-excision phase. Group B patients had higher SM grade AVMs, and the excision of these larger low resistance circulatory shunts could have resulted in a sudden increase in afterload, thereby increasing the MAP. This higher MAP and an ipsilateral rSO<sub>2</sub> drift > 12% in this group in the immediate post-excision phase warranted higher doses of sodium nitroprusside (p=0.01) to achieve optimal BP control in this group. This could also explain the significant higher intragroup increase in HR and decreased SBP and DBP observed in group B patients. Sodium nitroprusside (SNP) is a potent arterial and venous dilator that can cause immediate hypotension with reflex tachycardia. SNP has been used intraoperatively for controlled hypotension.(66)

Though the ipsilateral pre-excision rSO<sub>2</sub> values between the two groups were comparable, there was a significant increase in rSO<sub>2</sub> in group B patients during the post-excision phase (p<0.01). While none of the patients in Group A had an ipsilateral positive rSO<sub>2</sub> drift > 12% post-AVM excision, four patients in Group B had a positive ipsilateral drift of >12 % after excision in Group B (80%). Moreover, we noted that patients in Group B had a mean ipsilateral drift of 12.01± 2.63 % at the immediate post-excision phase, which was significantly higher as compared to 4.98 ± 5.7% in patients in Group A (p=0.02). This could be attributed to the increased redistribution of the CBF to the perinidal and surrounding brain tissue. Under anaesthesia, the CMRO<sub>2</sub> and the FiO<sub>2</sub> remain constant, and an increase in rSO<sub>2</sub> signifies an increase in CBF.(8) Thus, most of the patients in Group B had acute hyperemia in the immediate post-excision phase, requiring high doses of SNP to lower the BP to target a rSO<sub>2</sub> drift < 12%.

In the postoperative period, on admission to ICU, Group B patients had a significantly higher mean rSO<sub>2</sub> drift of  $14.78 \pm 0.08\%$  compared to  $6.88 \pm 4.5\%$  in Group A ( $p < 0.01$ ). Moreover, four patients (80%) in group B had a significant drop of rSO<sub>2</sub> postoperatively, in contrast to one patient (10%) in Group A had a significant drift  $>12\%$ , indicating a higher incidence of complications when rSO<sub>2</sub> drift was  $>12\%$ . A negative rSO<sub>2</sub> drift suggests a decline in regional oxygenation, which could be the precursor of the postoperative complications in these patients. Either it could be attributed to the regional ischemia seen in the patients with cerebral oedema and venous infarct, or it could be due to the increased oxygen extraction in patients with seizures.<sup>(67)</sup> One patient in group B with a bilateral drop in rSO<sub>2</sub> was diagnosed with cerebral oedema in the CT, indicating possibly global cerebral hypoperfusion. Also noteworthy is that in group B patients with an ipsilateral negative drift  $> 12\%$  in the postoperative period, the ipsilateral rSO<sub>2</sub> improved when the oxygenation, ventilation and blood pressure were optimised, and the rSO<sub>2</sub> drift reduced to  $< 12\%$ . Compared to other studies, this could have resulted in better patient outcomes in patients with postoperative complications.<sup>(68)</sup> We observed that a post-AVM excision ipsilateral rSO<sub>2</sub> drift  $>12\%$  and a postoperative ipsilateral drift in rSO<sub>2</sub> $>14.9\%$  from baseline were associated with complications in our patients.

The highest incidence of postoperative clinical events in our study was seizures. The incidence of generalised seizures in our study was 26.6 %, comparable to the findings of Englot et al., who reported an incidence of 12% -57 % after AVM resection. They reported that none of the factors associated with preoperative seizures, such as male gender, haemorrhage and frontotemporal location, were associated with postoperative seizures. Higher seizure incidence has been reported

with incomplete AVM obliteration and AVMs with deep perforators. (69) The microsurgical dissection required to isolate deep artery perforators from parenchyma has an irritative effect on the surrounding brain, resulting in a high incidence of postoperative seizures. (69) In our study, four patients had generalised seizures in the postoperative period. Among these four patients, three patients had SM grade III with deep perforators in the preoperative angiogram. Moreover, two out of these four patients had residual AVMs in the postoperative imaging. Riedel et al. reported 41% and 18% incidence of transient and permanent neurological deficits to post AVM excision.(6) In our study, one patient (7%) developed grade 3 limb weakness postoperatively due to a perinidal cerebral infarct. Stagnant arterial flow in the arterial feeders and retrograde thrombosis of feeding arteries post-resection of an AVM could lead to perinidal ischemia.(70) A surgical series by Miyasaka et al. described a 14% incidence of retrograde thrombosis of the feeding artery post AVM resection resulting in neurological symptoms. (71) Theofanis et al studied 264 patients with cerebral AVMs to assess the safety of microsurgical excision and determine predictors of complications. They determined that unruptured and larger AVMs were associated with higher complication rates and also reported a mortality rate of 2.7% in ruptured AVMs and 0.67% in unruptured AVMs. No case fatality occurred in our study. (72)

In our study, the optimal blood pressure management guided by rSO<sub>2</sub> enabled us to identify cerebral hyperemia and ischemia ahead of clinical manifestations, which aided in the optimal management of our patients. Therefore, our study chose a drift of >12% as significant. This value was extrapolated from literature in Carotid Endarterectomy (CEA) surgeries where NIRS was used to detect cerebral ischemia

or hyperemia.(61) Since the peri-operative cerebral hemodynamic changes encountered in CEA surgeries are similar to that in AVM surgeries, >12% rSO<sub>2</sub> change was considered significant in our study. (61) An increase of >12% in rSO<sub>2</sub> post excision prompted us to tightly control the blood pressure using SNP to avoid hyperemic complications. Due to this, the incidence of hyperemic complications was only 6.6 % in our study population. In our study, only one patient (6.6%) developed significant cerebral oedema postoperatively compared to 8- 21 % incidence reported by Badjer et al.(52) Badjer et al. also observed a higher incidence of hyperemic complications in larger size AVMs. They reported a 5% incidence of hyperemic complications in AVMs less than 3 cm and 35% in AVMs >6 cm in size. In addition, they reported a higher incidence of hyperemic complications in AVMs with deep perforators. Morgan et al. reported a 3% incidence of hyperemic complications, mainly in AVMs >4 cm and in patients with increased post-excision blood pressures. (53) Another study by Morgan et al. reported a 2.6% incidence of perioperative haemorrhage in a series of 112 patients for complete surgical excision of AVM.(68) They found by logistic regression that the most critical factor influencing the occurrence of complications in this series was the AVM size (p = 0.005). Four patients in our study had AVMs > 2.5 cm in size while the rest had AVMs < 2 cm, and four had AVMs with deep perforators. In Group B, most AVMs were grade III AVMs, followed by grade II AVMs, with no Grade I AVM. While in group A, i.e. in the group without complications, the majority were grade I and II AVMs. This association of higher incidence of complications in higher grade AVMs was similar to previous studies on AVMs showing a higher incidence of complications with

higher grade AVMs.(52) None of our patients developed intraoperative or postoperative haemorrhage.

Chui et al. reported an incidence of 4.4% hyperemic complications after AVM resection.(5) However, in their study majority were low-grade AVMs, and 33% of the patients had undergone preoperative embolization. The median postoperative systolic BP target in the study by Chui et al. was 110 (100–120) mmHg, and > 50% of the patients had failed hemodynamic control resulting in hypertensive surges in the postoperative period. Also, the uses of anti-hypertensive agents were common, and Labetalol was the most commonly used antihypertensive, followed by SNP.(5) In our study, especially in Group B, the majority were SM grade II AVMs (40%) and SM grade III AVMs(60%). None of our patients had undergone preoperative embolization. SNP was used as the sole antihypertensive agent, and mean arterial blood pressure in groups A and B was comparable ( $77.88 \pm 5.26$  mmHg vs  $77.45 \pm 5.29$  mmHg) with no episodes of hypertensive surges. However, it was observed that the mean arterial pressure was comparable across time points except at N<sub>5</sub>, i.e. post-excision, when the arterial pressure was significantly higher in group B (p-value 0.01). At this time point, the ipsilateral NIRS rSO<sub>2</sub> was also significantly higher in group B(>12% drift), which prompted us to tightly control the blood pressure with SNP(p value<0.01). Following this, the mean arterial pressures were reduced and better controlled, the hyperemia also reduced and the ipsilateral rSO<sub>2</sub> drift reduced to < 12%.

The strict blood pressure control overseen by NIRS monitoring might have contributed to our study's reduced prevalence of hyperemic complications, even in

higher-grade AVMs that had not undergone any preoperative embolization. The rSO<sub>2</sub> readings helped us determine each patient's crucial blood pressure targets. As a result, we could balance adequate brain oxygenation with avoidance of hyperemia simultaneously. Additionally, a rSO<sub>2</sub> drift >12% in our study population quickly alerted the clinicians to intervene efficiently to optimise the blood pressure. Of the two patients who experienced postoperative complications with a postoperative drift of less than 12 percent, one patient had an ipsilateral frontal EDH, which could have had an artefactual effect on the NIRS recordings. Extracerebral blood from the scalp or a subdural haemorrhage, non-heme tissue chromophores, and other factors can skew NIRS readings. (73)

While attempting to control blood pressure postoperatively, it is prudent to ensure adequate cerebral oxygenation, especially in the absence of monitors of cerebral oxygenation. The existing steal phenomenon in the surrounding perinidal tissues, thrombosis of the vessels, postoperative cerebral oedema and perforator injury could worsen the ischemic changes in the presence of induced hypotension. (3) Certain scenarios may necessitate induced hypertension to prevent ischemia. The AVM perinidal brain tissue is often chronically hypoperfused, making it exquisitely sensitive to interruption of normal blood flow. Thrombosis, embolization, retraction pressure, and temporary mechanical occlusion of feeding vessels can compromise already meagre blood flow to penumbral areas, thus necessitating a need to increase CPP and promote flow through collateral means. (3) Riedel et al. observed that the degree of induced hypotension and duration of hypotension were essential predictors of postoperative neurological deficits.(6) Their study chose a systolic blood pressure target of 80 mmHg. However, they noted that the patients who developed

postoperative neurological deficits in their study had higher values on the Spetzler-Martin scale (III vs II ;  $p = 0.082$ ), a significantly lower mean ABP ( $60 \pm 9$  mmHg vs  $69 \pm 11$  mmHg;  $p = 0.003$ ) and longer duration of arterial hypotension. We noted in our study that aggressive attempts to tightly control blood pressure in patients with a significant increase in  $rSO_2$  post-resection resulted in a significant unintended decrease in  $rSO_2 > 12\%$  in the postoperative period. If left undetected, this could have resulted in postoperative ischemic complications.

Monitoring regional cerebral oxygen saturation allows clinically silent episodes of cerebral ischemia to be detected. Various techniques have been employed for the early detection of perioperative cerebral ischemia and hypoxia, like electroencephalography (EEG), transcranial doppler (TCD), and brain tissue oxygen tension (PbtO<sub>2</sub>), and jugular venous oxygen saturation (SjVO<sub>2</sub>).<sup>(53)</sup> However, the use of these monitors is limited in the perioperative period due to multiple factors such as the need for trained personnel, being an indirect measure of oxygenation (EEG, TCD), invasive nature (PbtO<sub>2</sub>, SjVO<sub>2</sub>) and measurement of global cerebral oxygenation rather than regional oxygenation (EEG, TCD, SjVO<sub>2</sub>).<sup>(74)</sup> NIRS is a simple, real-time, non-invasive monitor with excellent correlation and agreeability with other monitors of cerebral oxygenation.<sup>(56,57)</sup> It can quickly alert the anesthesiologist or the intensivist to the changes in cerebral oxygenation and prompt further evaluation and time management. NIRS in neurovascular procedures provides quantifiable and continuous real-time information on cerebral oxygenation. <sup>(35)</sup>

Although the current literature recommends careful blood pressure control and keeping blood pressure below pre-operative baseline following resection surgery, none of them provides an optimum postoperative blood pressure target. This

may be the case because patient-to-patient variations exist in the parameters that affect the frequency of hyperemic consequences, such as SM grade and degree of autoregulatory failure in the perinidal vessels. To define individual blood pressure targets and manage patients effectively, blood pressure titrations guided by NIRS will be helpful. Therefore, blood pressure titrations guided by NIRS will help to identify individual blood pressure targets and optimally manage patients. We observed that a post-AVM excision ipsilateral  $rSO_2$  drift  $>12\%$  and a postoperative ipsilateral drift in  $rSO_2 >14.9\%$  from baseline were associated with complications in our patients. Therefore, an ipsilateral drift  $> 12\%$  should be treated with caution and close observation, while an ipsilateral  $rSO_2$  drift  $>14.9\%$  postoperatively warrants immediate evaluation and appropriate management.

***Limitations of the study:***

1. This was a pilot observational study; further randomised control trials comparing the outcome of patients who had NIRS guided management versus those who did not are needed to provide further evidence on the outcome measures
2. This was a single-centre study; thus, our observations need additional validation from multicentre studies.
3. Other modalities of cerebral oxygenation monitoring such as  $SjVO_2$  or TCD were not used to correlate the findings. Hence any erroneous NIRS readings could not be correlated with other cerebral oxygenation monitors and hence validated.
4. Since posterior circulation AVMs were excluded in our study, our results cannot be extrapolated to this subset of patients.



**SUMMARY AND CONCLUSION**

## 6. SUMMARY AND CONCLUSION

We hypothesised that NIRS-guided perioperative management can aid in prediction and prevention of perioperative complications in patients presenting for surgical excision of cerebral AVMs. In addition, we intended to identify a threshold value of rSO<sub>2</sub> to predict the incidence of perioperative complications.

This was a prospective observational study involving patients undergoing supratentorial AVM resection surgeries. rSO<sub>2</sub> and hemodynamic monitoring were done intraoperatively and postoperatively for 24 hours. A drift in rSO<sub>2</sub> >12% and perioperative events were recorded and analyzed. For analysis, patients were categorized into two groups, Group A - patients without complications and Group B - patients who had complications postoperatively. Five patients developed postoperative complications (33.3%) and were included in group B and the rest in group A. Fifty percent of the AVMs were SM grade II, 28.5% were SM grade I, and 21.4% were SM grade III. Post AVM excision, there was a significant increase in the mean ipsilateral rSO<sub>2</sub> from the baseline in group B patients, as compared to group A [ $12.01 \pm 2.63$  % vs  $4.98 \pm 5.7$  %, (p= 0.005) ] with 80% of the patients having an ipsilateral mean rSO<sub>2</sub> drift of >12%. Postoperatively, patients in group B had a significant negative mean rSO<sub>2</sub> drift as compared to group A [ $14.96 \pm 0.080$  % vs  $6.88 \pm 4.5$  % ,(p= 0.007)] with 80 % of the patients in group B having an ipsilateral rSO<sub>2</sub> drift of >12%. Thus with the help of NIRS rSO<sub>2</sub> drift we were able to timely detect both hyperemia and ischemia and intervene appropriately. The incidence of postoperative complications was 33.3% in our study with the highest incidence for generalized seizures 26.6%, followed by reintubation and prolonged ventilation in

13.3%, followed by EDH (6.6%), global cerebral edema(6.6%) and venous infarct with new onset neurological deficit(6.6%).

***Conclusions:***

- Near Infrared Spectroscopy can help detect changes in regional cerebral oxygenation caused by hyperemia or ischemia during cerebral AVM resection, and any significant drift could alert the physician to implement a timely intervention.
- In patients undergoing excision of cerebral AVMs, an intraoperative ipsilateral rSO<sub>2</sub> drift > 12 % should be treated with caution and close observation in the postoperative period as these patients tend to develop complications in the postoperative period.
- However, an ipsilateral rSO<sub>2</sub> drift >14.9% from the baseline in the postoperative period warrants immediate evaluation and appropriate management as it forecasts the incidence of an adverse clinical event in the near future.



**BIBLIOGRAPHY**

## **7. BIBLIOGRAPHY**

1. Sinha PK, Neema PK, Rathod RC. Anesthesia and intracranial arteriovenous malformation. *Neurol India*. 2004 Jun;52(2):163-70. PMID: 15269462.
2. Neema PK, Ramakrishnan S, Sinha PK, Rathod RC. Anesthetic implications of surgical repair of an aortocaval fistula. *J Cardiothorac Vasc Anesth*. 2003 Apr;17(2):236-9. PMID: 12698410.
3. Miller C, Mirski M. Anesthesia considerations and intraoperative monitoring during surgery for arteriovenous malformations and dural arteriovenous fistulas. *Neurosurg Clin N Am*. 2012 Jan;23(1):153-64. PMID: 22107866.
4. Spetzler RF, Wilson CB, Weinstein P, Mehdorn M, Townsend J, Telles D. Normal perfusion pressure breakthrough theory. *Clin Neurosurg*. 1978;25:651-72. PMID: 710017.
5. Chui J, Niazi B, Venkatraghavan L. Postoperative hemodynamic management in patients undergoing resection of cerebral arteriovenous malformations: A retrospective study. *J Clin Neurosci*. 2020 Feb;72:151-157. PMID: 31911109.
6. Riedel K, Thudium M, Boström A, Schramm J, Soehle M. Controlled arterial hypotension during resection of cerebral arteriovenous malformations. *BMC Neurol*. 2021 Sep 6;21(1):339. PMID: 34488658; PMCID: PMC8420011.
7. al-Rodhan NR, Sundt TM Jr, Piepgras DG, Nichols DA, Rüfenacht D, Stevens LN. Occlusive hyperemia: a theory for the hemodynamic complications following resection of intracerebral arteriovenous malformations. *J Neurosurg*. 1993 Feb;78(2):167-75. PMID: 8421198.

8. Murkin JM, Arango M. Near-infrared spectroscopy as an index of brain and tissue oxygenation. *Br J Anaesth.* 2009 Dec;103 Suppl 1:i3-13. PMID: 20007987.
9. Black S, Sulek CA, Day AL. Cerebral aneurysm and arteriovenous malformation. In: Cucchiara RF, Black S, Michenfelder JD, eds. *Clinical Neuroanaesthesia.* 2nd (Ed). New York: Churchill Livingstone 2000:265-318.
10. Millar C, Bissonnette B, Humphreys RP. Cerebral arteriovenous malformations in children. *Can J Anaesth.* 1994 Apr;41(4):321-31. PMID: 8004740.
11. Spetzler RF, Martin NA, Carter LP, Flom RA, Raudzens PA, Wilkinson E. Surgical management of large AVM's by staged embolization and operative excision. *J Neurosurg.* 1987 Jul;67(1):17-28. PMID: 3598668.
12. Martin N. A., Vinters H. V. Arteriovenous malformations. In: Carter L. P., Spetzler R. F., Hamilton M. G., editors. *Neurovascular Surgery.* New York, NY, USA: McGraw-Hill; 1995. pp. 875–903.
13. Fogarty-Mack P, Pile-Spellman J, Haccin-Bey L, Osipov A, DeMeritt J, Jackson EC, Young WL. The effect of arteriovenous malformations on the distribution of intracerebral arterial pressures. *AJNR Am J Neuroradiol.* 1996 Sep;17(8):1443-9. PMID: 8883639; PMCID: PMC8338719.
14. Young WL, Prohovnik I, Ornstein E, Ostapkovich N, Sisti MB, Solomon RA, Stein BM. The effect of arteriovenous malformation resection on cerebrovascular reactivity to carbon dioxide. *Neurosurgery.* 1990 Aug;27(2):257-66; discussion 266-7. PMID: 2117261.

15. Charbel FT, Hoffman WE, Misra M, Ausman JI. Increased brain tissue oxygenation during arteriovenous malformation resection. *Neurol Med Chir (Tokyo)*. 1998;38 Suppl:171-6. PMID: 10235002.
16. Morgan MK, Winder M, Little NS, Finfer S, Ritson E. Delayed hemorrhage following resection of an arteriovenous malformation in the brain. *J Neurosurg*. 2003 Dec;99(6):967-71. PMID: 14705722.
17. Frizzel RT, Fisher WS 3rd. Cure, morbidity, and mortality associated with embolization of brain arteriovenous malformations: a review of 1246 patients in 32 series over a 35-year period. *Neurosurgery*. 1995 Dec;37(6):1031-9; discussion 1039-40. PMID: 8584142.
18. Viñuela F, Dion JE, Duckwiler G, Martin NA, Lylyk P, Fox A, Pelz D, Drake CG, Girvin JJ, Debrun G. Combined endovascular embolization and surgery in the management of cerebral arteriovenous malformations: experience with 101 cases. *J Neurosurg*. 1991 Dec;75(6):856-64. PMID: 1941114.
19. Sakabe T, Nakakimura K. Effects of anesthetic agents and other drugs on cerebral blood flow, metabolism and intracranial protection. In: Cottrell JE, Smith DS, eds *Anaesthesia and Neurosurgery*. 4th (Ed). Mosby: St. Louis 2002:129-43.
20. Frizzell RT, Meyer YJ, Borchers DJ, Weprin BE, Allen EC, Pogue WR, Reisch JS, Cherrington AD, Batjer HH. The effects of etomidate on cerebral metabolism and blood flow in a canine model for hypoperfusion. *J Neurosurg*. 1991 Feb;74(2):263-9. PMID: 1988597.

21. Watson JC, Drummond JC, Patel PM, Sano T, Akrawi W, U HS. An assessment of the cerebral protective effects of etomidate in a model of incomplete forebrain ischemia in the rat. *Neurosurgery*. 1992 Apr;30(4):540-4. PMID: 1584352.
22. Cheng MA, Theard MA, Tempelhoff R. Intravenous agents and intraoperative neuroprotection. Beyond barbiturates. *Crit Care Clin*. 1997 Jan;13(1):185-99. PMID: 9012581.
23. Ravussin P, de Tribolet N. Total intravenous anesthesia with propofol for burst suppression in cerebral aneurysm surgery: preliminary report of 42 patients. *Neurosurgery*. 1993 Feb;32(2):236-40 discussion 240. PMID: 8437662.
24. Kaisti KK, Metsähonkala L, Teräs M, Oikonen V, Aalto S, Jääskeläinen S, Hinkka S, Scheinin H. Effects of surgical levels of propofol and sevoflurane anesthesia on cerebral blood flow in healthy subjects studied with positron emission tomography. *Anesthesiology*. 2002 Jun;96(6):1358-70. PMID: 12170048.
25. Schlünzen L, Juul N, Hansen KV, Cold GE. Regional cerebral blood flow and glucose metabolism during propofol anaesthesia in healthy subjects studied with positron emission tomography. *Acta Anaesthesiol Scand*. 2012 Feb;56(2):248-55. PMID: 22091956.
26. Fiset P, Paus T, Daloz T, Plourde G, Meuret P, Bonhomme V, Hajj-Ali N, Backman SB, Evans AC. Brain mechanisms of propofol-induced loss of consciousness in humans: a positron emission tomographic study. *J Neurosci*. 1999 Jul 1;19(13):5506-13. PMID: 10377359; PMCID: PMC6782309.

27. Alkire MT, Haier RJ, Barker SJ, Shah NK, Wu JC, Kao YJ. Cerebral metabolism during propofol anesthesia in humans studied with positron emission tomography. *Anesthesiology*. 1995 Feb;82(2):393-403; discussion 27A. PMID: 7856898.
28. Petersen KD, Landsfeldt U, Cold GE, Petersen CB, Mau S, Hauerberg J, Holst P, Olsen KS. Intracranial pressure and cerebral hemodynamic in patients with cerebral tumors: a randomized prospective study of patients subjected to craniotomy in propofol-fentanyl, isoflurane-fentanyl, or sevoflurane-fentanyl anesthesia. *Anesthesiology*. 2003 Feb;98(2):329-36. PMID: 12552189.
29. Schlünzen L, Vafaee MS, Cold GE, Rasmussen M, Nielsen JF, Gjedde A. Effects of subanaesthetic and anaesthetic doses of sevoflurane on regional cerebral blood flow in healthy volunteers. A positron emission tomographic study. *Acta Anaesthesiol Scand*. 2004 Nov;48(10):1268-76. PMID: 15504187.
30. Matta BF, Heath KJ, Tipping K, Summors AC. Direct cerebral vasodilatory effects of sevoflurane and isoflurane. *Anesthesiology*. 1999 Sep;91(3):677-80. PMID: 10485778.
31. Schlünzen L, Juul N, Hansen KV, Gjedde A, Cold GE. Regional cerebral glucose metabolism during sevoflurane anaesthesia in healthy subjects studied with positron emission tomography. *Acta Anaesthesiol Scand*. 2010 May;54(5):603-9. PMID: 20085540.
32. Kaisti KK, Långsjö JW, Aalto S, Oikonen V, Sipilä H, Teräs M, Hinkka S, Metsähonkala L, Scheinin H. Effects of sevoflurane, propofol, and adjunct nitrous oxide on regional cerebral blood flow, oxygen consumption, and blood volume in humans. *Anesthesiology*. 2003 Sep;99(3):603-13. PMID: 12960544.

33. Davie SN, Grocott HP. Impact of extracranial contamination on regional cerebral oxygen saturation: a comparison of three cerebral oximetry technologies. *Anesthesiology*. 2012 Apr;116(4):834-40. PMID: 22343469.
34. Ghosh A, Elwell C, Smith M. Review article: cerebral near-infrared spectroscopy in adults: a work in progress. *Anesth Analg*. 2012 Dec;115(6):1373-83. PMID: 23144435.
35. Calderon-Arnulphi M, Alaraj A, Amin-Hanjani S, Mantulin WW, Polzonetti CM, Gratton E, Charbel FT. Detection of cerebral ischemia in neurovascular surgery using quantitative frequency-domain near-infrared spectroscopy. *J Neurosurg*. 2007 Feb;106(2):283-90. PMID: 17410713.
36. Holzschuh M, Woertgen C, Metz C, Brawanski A. Dynamic changes of cerebral oxygenation measured by brain tissue oxygen pressure and near infrared spectroscopy. *Neurol Res*. 1997 Jun;19(3):246-8. PMID: 9192374.
37. Jöbsis FF. Noninvasive, infrared monitoring of cerebral and myocardial oxygen sufficiency and circulatory parameters. *Science*. 1977 Dec 23;198(4323):1264-7. PMID: 929199.
38. Owen-Reece H, Smith M, Elwell CE, Goldstone JC. Near infrared spectroscopy. *Br J Anaesth*. 1999 Mar;82(3):418-26. PMID: 10434827.
39. McCormick PW, Stewart M, Goetting MG, Dujovny M, Lewis G, Ausman JI. Noninvasive cerebral optical spectroscopy for monitoring cerebral oxygen delivery and hemodynamics. *Crit Care Med*. 1991 Jan;19(1):89-97. PMID: 1986896.

40. Choi J, Wolf M, Toronov V, Wolf U, Polzonetti C, Hueber D, Safonova LP, Gupta R, Michalos A, Mantulin W, Gratton E. Noninvasive determination of the optical properties of adult brain: near-infrared spectroscopy approach. *J Biomed Opt.* 2004 Jan-Feb;9(1):221-9. PMID: 14715077.
41. Kim MN, Durduran T, Frangos S, Edlow BL, Buckley EM, Moss HE, Zhou C, Yu G, Choe R, Maloney-Wilensky E, Wolf RL, Grady MS, Greenberg JH, Levine JM, Yodh AG, Detre JA, Kofke WA. Noninvasive measurement of cerebral blood flow and blood oxygenation using near-infrared and diffuse correlation spectroscopies in critically brain-injured adults. *Neurocrit Care.* 2010 Apr;12(2):173-80. PMID: 19908166; PMCID: PMC2844468.
42. Pollard V, Prough DS, DeMelo AE, Deyo DJ, Uchida T, Stoddart HF. Validation in volunteers of a near-infrared spectroscope for monitoring brain oxygenation in vivo. *Anesth Analg.* 1996 Feb;82(2):269-77. PMID: 8561326.
43. Watzman HM, Kurth CD, Montenegro LM, Rome J, Steven JM, Nicolson SC. Arterial and venous contributions to near-infrared cerebral oximetry. *Anesthesiology.* 2000 Oct;93(4):947-53.. PMID: 11020744.
44. Fox E, Jöbsis-Vander Vliet FF, Mitnick MH. Monitoring cerebral oxygen sufficiency in anesthesia and surgery. *Adv Exp Med Biol.* 1985;191:849-54. PMID: 3008517.
45. Fuchs G, Schwarz G, Kulier A, Litscher G. The influence of positioning on spectroscopic measurements of brain oxygenation. *J Neurosurg Anesthesiol.* 2000 Apr;12(2):75-80.. PMID: 10774599.

46. Picton P, Chambers J, Shanks A, Dorje P. The influence of inspired oxygen fraction and end-tidal carbon dioxide on post-cross-clamp cerebral oxygenation during carotid endarterectomy under general anesthesia. *Anesth Analg.* 2010 Feb 1;110(2):581-7. PMID: 19955500.
47. Grocott HP. Avoid hypotension and hypoxia: an old anesthetic adage with renewed relevance from cerebral oximetry monitoring. *Can J Anaesth.* 2011 Aug;58(8):697-702. PMID: 21643871.
48. Firbank M, Okada E, Delpy DT. A theoretical study of the signal contribution of regions of the adult head to near-infrared spectroscopy studies of visual evoked responses. *Neuroimage.* 1998 Jul;8(1):69-78. PMID: 9698577.
49. Van der Zee P, Arridge SR, Cope M, Delpy DT. The effect of optode positioning on optical pathlength in near infrared spectroscopy of brain. *Adv Exp Med Biol.* 1990;277:79-84.. PMID: 2096679
50. Arikan F, Vilalta J, Noguer M, Olive M, Vidal-Jorge M, Sahuquillo J. Intraoperative monitoring of brain tissue oxygenation during arteriovenous malformation resection. *J Neurosurg Anesthesiol.* 2014 Oct;26(4):328-41. PMID: 24492516.
51. Asgari S, Röhrborn HJ, Engelhorn T, Fauser B, Stolke D. Intraoperative measurement of cortical oxygen saturation and blood volume adjacent to cerebral arteriovenous malformations using near-infrared spectroscopy. *Neurosurgery.* 2003 Jun;52(6):1298-304; discussion 1304-6. PMID: 12762875.
52. Batjer HH, Devous MD Sr, Seibert GB, Purdy PD, Bonte FJ. Intracranial arteriovenous malformation: relationship between clinical factors and surgical complications. *Neurosurgery.* 1989 Jan;24(1):75-9. PMID: 2927602.

53. Morgan MK, Sekhon LH, Finfer S, Grinnell V. Delayed neurological deterioration following resection of arteriovenous malformations of the brain. *J Neurosurg.* 1999 Apr;90(4):695-701. PMID: 10193615.
54. Deruty R, Pelissou-Guyotat I, Amat D, Mottolese C, Bascoulergue Y, Turjman F, Gerard JP. Complications after multidisciplinary treatment of cerebral arteriovenous malformations. *Acta Neurochir (Wien).* 1996;138(2):119-31. PMID: 8686534.
55. Bhatia R, Hampton T, Malde S, Kandala NB, Muammar M, Deasy N, Strong A. The application of near-infrared oximetry to cerebral monitoring during aneurysm embolization: a comparison with intraprocedural angiography. *J Neurosurg Anesthesiol.* 2007 Apr;19(2):97-104. PMID: 17413995.
56. Rivera-Lara L, Geocadin R, Zorrilla-Vaca A, Healy R, Radzik BR, Palmisano C, Mirski M, Ziai WC, Hogue C. Validation of Near-Infrared Spectroscopy for Monitoring Cerebral Autoregulation in Comatose Patients. *Neurocrit Care.* 2017 Dec;27(3):362-369. PMID: 28664392; PMCID: PMC5772737.
57. Taussky P, O'Neal B, Daugherty WP, Luke S, Thorpe D, Pooley RA, Evans C, Hanel RA, Freeman WD. Validation of frontal near-infrared spectroscopy as noninvasive bedside monitoring for regional cerebral blood flow in brain-injured patients. *Neurosurg Focus.* 2012 Feb;32(2):E2. PMID: 22296679.
58. Lovell AT, Owen-Reece H, Elwell CE, Smith M, Goldstone JC. Continuous measurement of cerebral oxygenation by near infrared spectroscopy during induction of anesthesia. *Anesth Analg.* 1999 Mar;88(3):554-8. PMID: 10072005.

59. Fleck T, Schubert S, Ewert P, Stiller B, Nagdyman N, Berger F. Propofol effect on cerebral oxygenation in children with congenital heart disease. *Pediatr Cardiol.* 2015 Mar;36(3):543-9. PMID: 25311762.
60. Iwasaki K, Nomoto Y, Ishiwata M, Yokota T, Ogawa R. Vital capacity induction with 8% sevoflurane and N<sub>2</sub>O causes cerebral hyperemia. *J Anesth.* 2003;17(1):3-7. PMID: 12908681.
61. Wang Y, Li L, Wang T, Zhao L, Feng H, Wang Q, Fan L, Feng X, Xiao W, Feng K. The Efficacy of Near-Infrared Spectroscopy Monitoring in Carotid Endarterectomy: A Prospective, Single-Center, Observational Study. *Cell Transplant.* 2019 Feb;28(2):170-175. PMID: 30545240; PMCID: PMC6362521.
62. Ogilvy CS, Stieg PE, Awad I, Brown RD Jr, Kondziolka D, Rosenwasser R, Young WL, Hademenos G; Special Writing Group of the Stroke Council, American Stroke Association. AHA Scientific Statement: Recommendations for the management of intracranial arteriovenous malformations: a statement for healthcare professionals from a special writing group of the Stroke Council, American Stroke Association. *Stroke.* 2001 Jun;32(6):1458-71. PMID: 11387517.
63. Trafidło T, Gaszyński T, Gaszyński W, Nowakowska-Domagala K. Intraoperative monitoring of cerebral NIRS oximetry leads to better postoperative cognitive performance: a pilot study. *Int J Surg.* 2015 Apr;16(Pt A):23-30. PMID: 25701620.

64. Ajiboye N, Chalouhi N, Starke RM, Zanaty M, Bell R. Cerebral arteriovenous malformations: evaluation and management. *ScientificWorldJournal*. 2014;2014:649036.PMID: 25386610; PMCID: PMC4216697.
65. Söderman M, Andersson T, Karlsson B, Wallace MC, Edner G. Management of patients with brain arteriovenous malformations. *Eur J Radiol*. 2003 Jun;46(3):195-205.PMID: 12758114 .
66. Nguyen LP, Gerstein NS. Cardiovascular pharmacology in non-cardiac surgery. In: Kaplan JA, Cronin B, Maus TM (Eds.), *Essentials of Cardiac Anesthesia for Noncardiac Surgery* (247-288). New York, NY: Elsevier,2019,pp.247-288
67. Meldrum B, Chapman A. Metabolic Consequences of Seizures. In: Siegel GJ, Agranoff BW, Albers RW, et al., editors. *Basic Neurochemistry: Molecular, Cellular and Medical Aspects*. 6th edition. Philadelphia: Lippincott-Raven; 1999.
68. Morgan MK, Johnston IH, Hallinan JM, Weber NC. Complications of surgery for arteriovenous malformations of the brain. *J Neurosurg*. 1993 Feb;78(2):176-82. PMID: 8421199.
69. Englot DJ, Young WL, Han SJ, McCulloch CE, Chang EF, Lawton MT. Seizure predictors and control after microsurgical resection of supratentorial arteriovenous malformations in 440 patients. *Neurosurgery*. 2012 Sep;71(3):572-80; discussion 580. PMID: 22592327; PMCID: PMC5815296.

70. Miyasaka Y, Yada K, Ohwada T, Kitahara T, Endoh M, Saito M, Kurata A, Ohtaka H. Retrograde thrombosis of feeding arteries after removal of arteriovenous malformations. *J Neurosurg.* 1990 Apr;72(4):540-5. PMID: 2319311.
71. Miyasaka Y, Yada K, Ohwada T, Kitahara T, Kurata A, Irikura K. Pathophysiologic assessment of stagnating arteries after removal of arteriovenous malformations. *AJNR Am J Neuroradiol.* 1993 Jan-Feb;14(1):15-8. PMID: 8427078; PMCID: PMC8334459.
72. Theofanis T, Chalouhi N, Dalyai R, Starke RM, Jabbour P, Rosenwasser RH, Tjoumakaris S. Microsurgery for cerebral arteriovenous malformations: postoperative outcomes and predictors of complications in 264 cases. *Neurosurg Focus.* 2014 Sep;37(3):E10. PMID: 25175429.
73. Salonia R, Bell MJ, Kochanek PM, Berger RP. The utility of near infrared spectroscopy in detecting intracranial hemorrhage in children. *J Neurotrauma.* 2012 Apr 10;29(6):1047-53. PMID: 22098538; PMCID: PMC3325547.
74. Hernandez-Avila G, Dujovny M, Slavin KV, Luer MS, Nijensohn E, Geremia G, Ausman JI. Use of transcranial cerebral oximetry to monitor regional cerebral oxygen saturation during neuroendovascular procedures. *AJNR Am J Neuroradiol.* 1995 Sep;16(8):1618-25. PMID: 7502964; PMCID: PMC8337761



**ANNEXURES**

## PROFORMA

**Title-** Efficacy of near infrared spectroscopy guided anesthetic management to predict and prevent the incidence of perioperative complications in patients presenting for surgical excision of cerebral arteriovenous malformation.

Patient Age /sex:

Date:

Diagnosis:

Location of AVM:

Number of feeders and draining vein :

Preoperative Hb:

Size of Nidus:

Clinical Presentaion:

ECHO/ECG:

**Note- Any change in NIRS value >12% from baseline is significant**

Time Points	NIRS Value				HR	SBP	DBP	MAP	EtCo2	SpO <sub>2</sub>	Pleth Index	delta SpO <sub>2</sub>
	Ipsilateral	ΔrSO <sub>2</sub>	Contralateral	ΔrSO <sub>2</sub>								
N <sub>1</sub> -Baseline prior to induction												
N <sub>2</sub> -10 min after induction												
N <sub>3</sub> -After arterial occlusion/ligation												
N <sub>4</sub> -Postvenous occlusion/ligation												
N5- Postresection/ embolisation of AVM												
N6- First value in ICU												

Elaborate Intraoperative Events (Significant Change in NIRS, event during which change was noted, what intervention was done,Bleed/brain bulge etc):-

Intraop blood loss- ml , Transfusion-ml

NIRs value :- Prior to transfusion

End of transfusion -

ABG	Po2	Pco2	Hb	Lactate
Baseline				
Prior to transfusion				
After Transfusion				
In ICU				

Postoperative

Time after procedure (in Hours)	SBP	DBP	MAP	HR	PPV	SpO <sub>2</sub>	NIRS value		Postoperative complications. (Tick against relevant)
							Ipsilateral	Contralateral	
P1									Reexploration/Surgery/EVD <input type="checkbox"/>
P2									Cerebral Ischemia/infarct <input type="checkbox"/>
P3									Bleed/Hemorrhage <input type="checkbox"/>
P4									Cerebral edema <input type="checkbox"/>
P5									Delayed Awakening <input type="checkbox"/>
P6									Seizures <input type="checkbox"/>
P7									Prolonged Ventilation <input type="checkbox"/>
P8									Reintubation/Tracheostomy <input type="checkbox"/>
P9									Embolism <input type="checkbox"/>
P10									Pneumonia/Sepsis <input type="checkbox"/>
P11									Others <input type="checkbox"/>
P12									
Pc(at time of complication)									

Time of Extubation:

Duration of ICU stay:

CT Scan-1) Immediate postop-

2) Post 12/24 hrs-

Elaborate Interventions done postop (Reintubation, Re explorations/EVD/ Neuroprotection/ hemodynamic supports

**Modified Rankin score at time of discharge(Tick relevant)**

mRS score	Description
0	No symptoms at all
1	No significant disability despite symptoms; able to carry out all usual duties and activities
2	Slight disability; unable to carry out all previous activities, but able to look after own affairs without assistance
3	Moderate disability; requiring some help (e.g. with shopping/managing affairs) but able to walk without assistance
4	Moderately severe disability; unable to walk without assistance and unable to attend to own bodily needs without assistance
5	Severe disability; bedridden, incontinent and requiring constant nursing care and attention
6	Dead

## CONSENT FORM

STUDY TITLE: **Efficacy of near infrared spectroscopy guided anesthetic management to predict and prevent the incidence of perioperative complications in patients presenting for surgical excision of cerebral arteriovenous malformation.**

Participant's name:

Age (in years):

I \_\_\_\_\_, son/daughter of \_\_\_\_\_

Declare that (Please tick boxes)

- I have read the above information provided to me regarding the study "[ ]
- I have clarified any doubts that I had. [ ]
- I also understand that my participation in this study is entirely voluntary and that I am free to withdraw permission to continue to participate at any time without affecting my usual treatment or my legal rights [ ]
- I understand that the study staff and institutional ethics committee members will not need my permission to look at my health records even if I withdraw from the trial. I agree to this access [ ]
- I understand that my identity will not be revealed in any information released to third parties or published [ ]
- I voluntarily agree to take part in this study [ ]
- I have been provided with the contact numbers of the principle investigator, in case I want to know more about the study and participants rights [ ].
- I received a copy of this signed consent form [ ]

Name:

Signature:

Date:

Name of witness:

Relation to participant:

Signature:

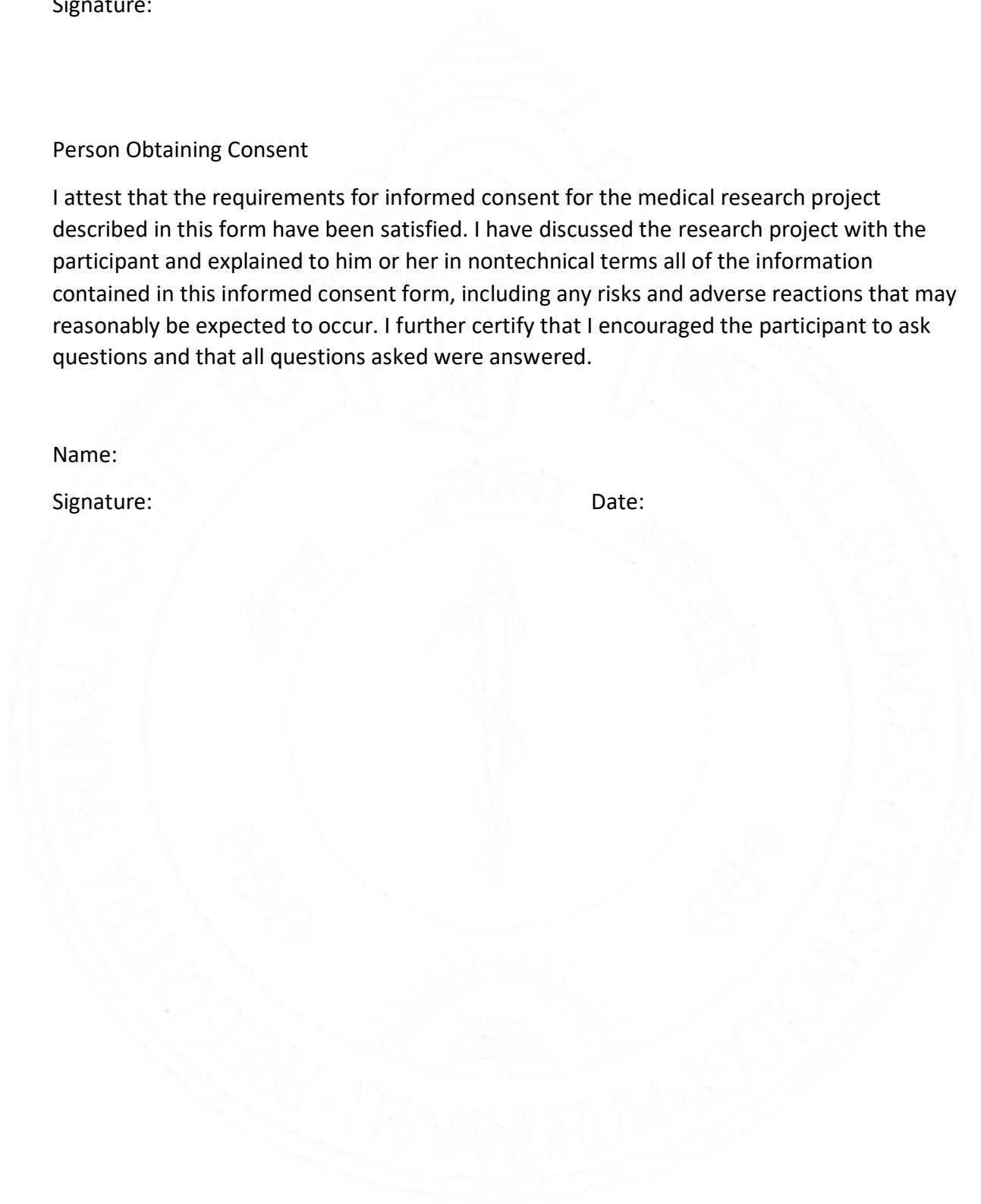
Person Obtaining Consent

I attest that the requirements for informed consent for the medical research project described in this form have been satisfied. I have discussed the research project with the participant and explained to him or her in nontechnical terms all of the information contained in this informed consent form, including any risks and adverse reactions that may reasonably be expected to occur. I further certify that I encouraged the participant to ask questions and that all questions asked were answered.

Name:

Signature:

Date:



സമ്മതപത്രം

ശീർഷകം: സുപ്രാടെന്റോറിയൽ ആർട്ടിരികളും വെയിനുകളും തമ്മിൽ അസാധാരണമായി ബന്ധപ്പെടുന്നതിനെ (ആർട്ടിരിയോവീനസ് മാൽഫോർമേഷൻ) ചികിത്സാപരമായി കൈകാര്യം ചെയ്യുന്നതിലും ശസ്ത്രക്രിയാസമയത്തെ സങ്കീർണ്ണതകളും ചികിത്സാപരമായ മുന്നറിവും വിലയിരുത്തുന്നതിലും നീയർ ഇൻഫ്രാ റെഡ് സ്പെക്ട്രോസ്കോപ്പിയുപയോഗിച്ച് തലച്ചോറിലെ പ്രാണവായു സമ്പുഷ്ടതയുടെ പ്രവണതകളുടെ നിരീക്ഷണത്തിന്റെ പ്രയോജനക്ഷമത. ഒരു പ്രാരംഭ നിരീക്ഷണാത്മക പഠനം.

പഠനത്തിൽ പങ്കെടുക്കാൻ ഞാൻ (പങ്കെടുക്കുന്നയാളുടെ പേര്) .....  
..... സമ്മതം നൽകുന്നു

ജനനതീയതി/വയസ്സ് ... ..... മാസങ്ങളിൽ/വർഷത്തിൽ) .....  
(അച്ഛൻ/അമ്മയുടെ പേര്)

(പ്രസക്തമായ കോളങ്ങളിൽ ശരിയടയാളമിടുക)

- എനിക്കു മുകളിൽ തന്ന കാര്യവിവരണപത്രം വായിച്ചു [ ]
- എനിക്കുണ്ടായ സംശയങ്ങൾ പരിഹരിച്ചു [ ]
- എന്റെ പങ്കാളിത്തം സ്വമേധയായാണെന്നും, എന്റെ പതിവ് ചികിത്സയെയോ നിയമപരമായ അവകാശങ്ങളോടോ ബാധിക്കാതെ ഏതു സമയത്തും പങ്കെടുക്കുന്നതിനുള്ള എന്റെ അനുവാദം പിൻവലിക്കാമെന്നും ഞാൻ മനസ്സിലാക്കുന്നു. [ ]
- പഠനത്തിൽനിന്നും ഞാൻ പിൻമാറിയാലും ഈ പഠനവുമായി ബന്ധപ്പെട്ട ആരോഗ്യരേഖകൾ പഠനസംഘത്തിനും നൈതീക കമ്മിറ്റി അംഗങ്ങൾക്കും എന്റെ അനുവാദം കൂടാതെ പരിശോധിക്കാമെന്ന് ഞാൻ മനസ്സിലാക്കുന്നു. അതിന് ഞാൻ സമ്മതിക്കുന്നു. [ ]
- എന്റെ വ്യക്തിപരമായവിവരങ്ങൾ മൂന്നാം കക്ഷികൾക്കോ പ്രസിദ്ധീകരണത്തിനോ നൽകില്ലെന്ന് ഞാൻ മനസ്സിലാക്കുന്നു. [ ]
- പഠനത്തെപ്പറ്റിയോ പങ്കെടുക്കുന്നവരുടെ അവകാശത്തെപ്പറ്റിയോ കൂടുതലറിയണമെങ്കിൽ എനിക്ക് ബന്ധപ്പെടാനുള്ള നമ്പരുകൾ നൽകിയിട്ടുണ്ട് [ ]
- ഞാൻ സ്വമേധയാ ഈ പഠനത്തിൽ പങ്കെടുക്കാൻ സമ്മതിക്കുന്നു. [ ]
- സമ്മതപത്രത്തിന്റെ ഒപ്പിട്ട ഒരു പ്രതി എനിക്ക് ലഭിച്ചു. [ ]

പേര്

ഒപ്പ്

തീയതി

സാക്ഷിയുടെ പേര്

രോഗിയുമായുള്ള ബന്ധം

ഒപ്പ്

സമ്മതപത്രം വാങ്ങുന്ന ആൾ

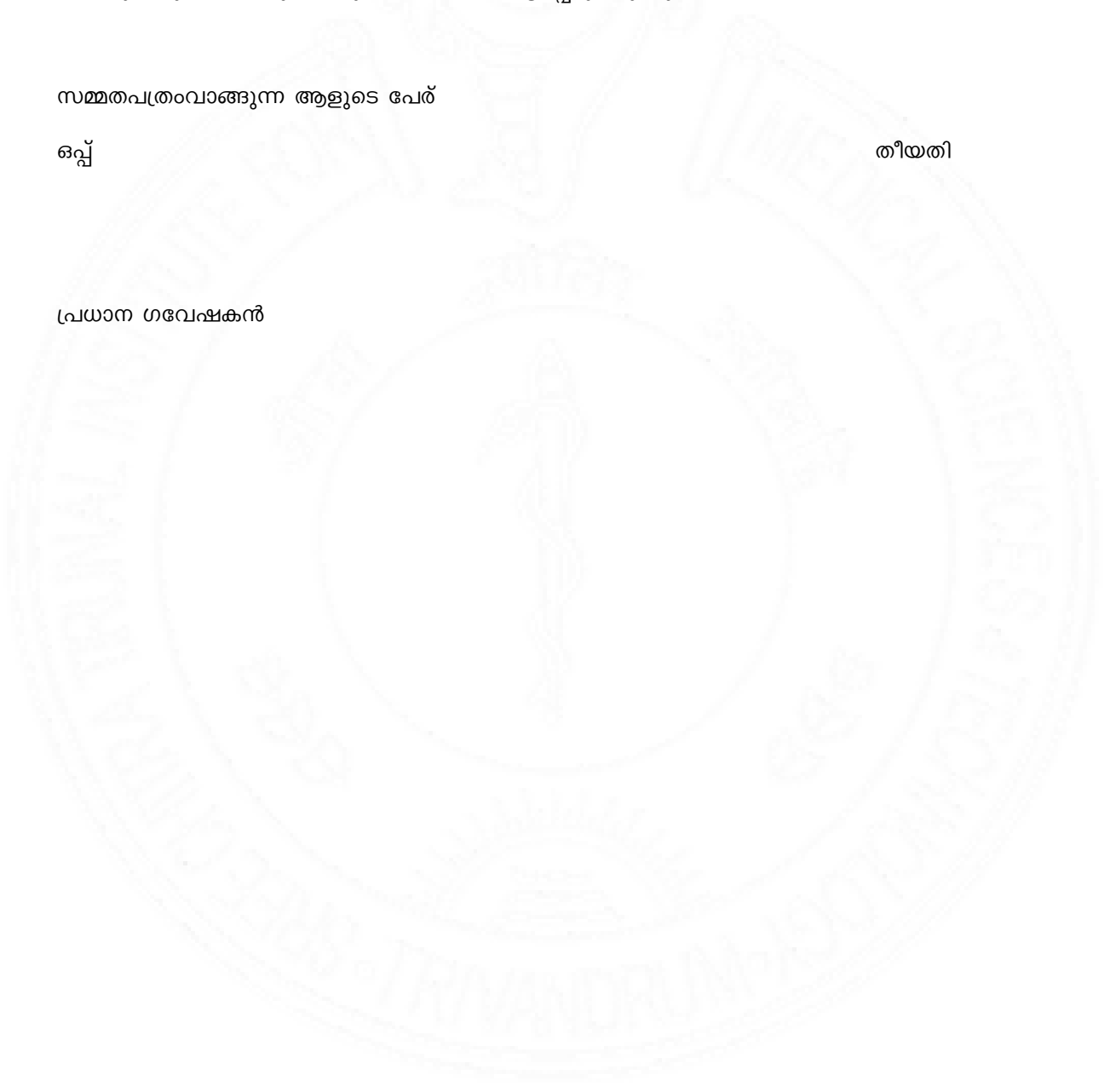
മെഡിക്കൽ റിസർച്ച് പ്രോജക്ടിനാവശ്യമായ സമ്മതപത്രത്തിനു വേണ്ടുന്ന എല്ലാ ഘടകങ്ങളും തൃപ്തികരമായി നിർവഹിച്ചിരിക്കുന്നുവെന്ന് ഞാൻ ബോധ്യപ്പെടുത്തുന്നു. പഠനപങ്കാളിയുമായി ഗവേഷണ പദ്ധതിയെപ്പറ്റി സാങ്കേതികേതര പദങ്ങളുപയോഗിച്ച് എല്ലാ വിവരങ്ങളെപ്പറ്റിയും ചർച്ച നടത്തുകയും പ്രതീക്ഷിക്കാവുന്ന അപകടസാധ്യതകളും പാർശ്വഫലങ്ങളും വിശദീകരിക്കുകയും ചെയ്തു. പങ്കാളിയെ ചോദ്യങ്ങൾ ചോദിക്കാൻ പ്രേരിപ്പിക്കുകയും എല്ലാ ചോദ്യങ്ങൾക്കും ഉത്തരം നൽകുകയും ചെയ്തു എന്നും ഞാൻ സാക്ഷ്യപ്പെടുത്തുന്നു.

സമ്മതപത്രം വാങ്ങുന്ന ആളുടെ പേര്

ഒപ്പ്

തീയതി

പ്രധാന ഗവേഷകൻ



## PATIENT INFORMATION SHEET

**TITLE : Efficacy of near infrared spectroscopy guided anesthetic management to predict and prevent the incidence of perioperative complications in patients presenting for surgical excision of cerebral arteriovenous malformation.**

**Name of the Investigators:** Dr.Jithumol Thankam Thomas (PI), Dr Ajay Prasad Hrishi P (guide and Co-PI), Dr.Ranganatha Praveen C S(Co-guide and Co-PI), Dr Manikandan Sethuraman(Co-PI), Dr Mathew Abraham(Co-I),Dr Jayadevan E R(Co-I).

You are being requested to participate in the above titled study which is being conducted to evaluate the usefulness of cerebral oxygenation monitoring using Near Infrared Spectroscopy (NIRS) for the timely detection of cerebral ischaemia and/or cerebral hyperemia in Arteriovenous malformation(AVM) resection surgeries and embolization procedure.

We have decided to recruit 20 people with intracranial AVM; 10 posted for elective AVM resection surgery and 10 posted for AVM embolization procedures at SCTIMST, Trivandrum. Patients in both groups will have intraoperative and postoperative monitoring of cerebral oxygen saturation using NIRS. NIRS is a non invasive technology that aids the anesthesiologist to monitor the oxygen levels in the brain when the patient is under anesthesia .

### **What is cerebral oxygenation monitoring by NIRS?**

Our brain needs a constant supply of oxygen and nutrients for its proper functioning. There are various methods for assessing cerebral oxygenation of which NIRS is a non-invasive technology that continuously monitors regional brain tissue oxygenation. It is monitored by placing a pair of adhesive electrodes on each forehead of the participant. This monitoring is done in patients with intracranial vascular pathologies such as AVM ,who are undergoing surgery or neuro intervention for the same. This monitor help in detecting any changes in the brain oxygen levels that can happen as a result of complication during or after the therapeutic intervention. Therefore monitoring this will help in early detection of the complications and help the clinician to do the necessary corrective measures to improve the outcome of the patient.

**If you take part what will you have to do?**

After the routine anesthetic preparation, NIRS electrodes will be stuck on to each forehead and its baseline value will be noted. It is a non-invasive monitor that is part of routine monitoring in patients undergoing therapeutic intervention for intracranial AVM. If you consent to participate, we will be monitoring the cerebral oxygenation with NIRS in the periprocedural period for up to 24 hours in the postprocedural period in ICU. This may be beneficial for you as it will aid in early detection of post-procedure complications of AVM before the patient becomes symptomatic. Additionally, this would help the clinician in predicting the treatment outcome. Thus with this study, we intend to improve the quality of care for the patients undergoing treatment for intracranial AVM.

**Do NIRS monitoring have any side effects?**

NIRS is a non-invasive technique it does not carry any risk. As per literature search, there are no known adverse events for this monitor.

**Can you withdraw from this study after it starts?**

Your participation in this study is entirely voluntary and you are also free to decide to withdraw permission to participate in this study. If you do so, this will not affect your usual treatment at this hospital in any way.

**Will you have to pay for the cost of using the test?**

These are used as a part of standard anesthesia monitoring for cerebral oxygenation in patients presenting for surgery or radiological intervention. So no additional cost will be charged for the patients if they consent to enroll in this study.

**Will your personal details be kept confidential?**

The results of this study will be used as a part of academic research and will be submitted to a medical journal for publication, but you will not be identified by name in any publication or presentation of results. However, your medical notes may be reviewed by people associated with the study, without your additional permission, should you decide to participate in this study.

If you have any further questions regarding the technical aspects of the study, please contact Dr. Jithumol Thankam Thomas(Principal investigator)  
mobile number: 9632094554. Email: [drjithu88@gmail.com](mailto:drjithu88@gmail.com)

For any queries or concerns related to the ethical conduct of this study , please contact Dr. Mala Ramanathan, telephone number: 0471-2524234. Email: [iec.mem.sec@sctimst.ac.in](mailto:iec.mem.sec@sctimst.ac.in)

**രോഗിക്കുള്ള കാര്യവിവരണപത്രം**

ശീർഷകം: സുപ്രാടെന്റോറിയൽ ആർട്ടീരികളും വെയിനുകളും തമ്മിൽ അസാധാരണമായി ബന്ധപ്പെടുന്നതിനെ (ആർട്ടീരിയോവീനസ് മാൽഫോർമേഷൻ) ചികിത്സാപരമായി കൈകാര്യം ചെയ്യുന്നതിലും ശസ്ത്രക്രിയാസമയത്തെ സങ്കീർണ്ണതകളും ചികിത്സാപരമായ മുന്നറിവും വിലയിരുത്തുന്നതിലും നീയർ ഇൻഫ്രാ റെഡ് സ്പെക്ട്രോസ്കോപ്പിയുപയോഗിച്ച് തലച്ചോറിലെ പ്രാണവായു സമ്പുഷ്ടതയുടെ പ്രവണതകളുടെ നിരീക്ഷണത്തിന്റെ പ്രയോജനക്ഷമത. ഒരു പ്രാരംഭ നിരീക്ഷണാത്മക പഠനം.

ഗവേഷകരുടെ പേര്: ഡോ. ജിതുമോൾ തങ്കം തോമസ് (പ്രധാന ഗവേഷക), ഡോ. അജയ് പ്രസാദ് ഹൃഷി ( ഗൈഡും സഹപ്രധാനഗവേഷകനും), ഡോ. രംഗനാഥ പ്രവീൺ(സഹ ഗൈഡും സഹ പ്രധാനഗവേഷകനും)

ആർട്ടീരിയോവീനസ് മാൽഫോർമേഷൻ (എവിഎം) നീക്കംചെയ്യാൻ ശസ്ത്രക്രിയ നടത്തുന്നതിനും എംബോളൈസേഷൻ നടപടികൾക്കും കൃത്യസമയത്ത് തലച്ചോറിലെ രക്തദൈർബല്യവും തലച്ചോറിലെ അമിതരക്തപ്രവാഹവും കണ്ടെത്താൻ നീയർ ഇൻഫ്രാ റെഡ് സ്പെക്ട്രോസ്കോപ്പി (എൻഐആർഎസ്) ഉപയോഗിച്ച് തലച്ചോറിലെ പ്രാണവായു സമ്പുഷ്ടത നിരീക്ഷണത്തിന്റെ പ്രയോജനക്ഷമത വിലയിരുത്തുന്ന മുകളിൽപറഞ്ഞ ശീർഷകത്തിലുള്ള പഠനത്തിൽ പങ്കെടുക്കാൻ താങ്കളെ ക്ഷണിക്കുന്നു.

തിരുവനന്തപുരം SCTIMSTയിൽ മുൻ നിശ്ചയപ്രകാരം എവിഎം നീക്കം ചെയ്യുന്നതിനു തീരുമാനിക്കപ്പെട്ട 10 പേരെയും എംബോളൈസേഷൻ തീരുമാനിക്കപ്പെട്ട 10 പേരെയും ഉൾപ്പെടെ എവിഎം ഉള്ള 20 പേരെ പഠനത്തിൽ പങ്കാളികളാക്കാൻ ഞങ്ങൾ ആസൂത്രണം ചെയ്യുന്നു. രണ്ട് സംഘത്തിലെ രോഗികളെയും ശസ്ത്രക്രിയാസമയത്തും ശസ്ത്രക്രിയയ്ക്കു ശേഷവും എൻഐആർഎസ് ഉപയോഗിച്ച് തലച്ചോറിലെ പ്രാണവായു സമ്പുഷ്ടത നിരീക്ഷിക്കും. ശരീരത്തിൽ കടക്കാതെയുള്ള ഒരു സാങ്കേതികതയാണ് എൻഐആർഎസ്.

**എൻഐആർഎസ് ഉപയോഗിച്ചുള്ള പ്രാണവായു സമ്പുഷ്ടത നിരീക്ഷണമെന്നാലെന്താണ്?**

നമ്മുടെ തലച്ചോറിന്റെ ശരിയായ പ്രവർത്തനത്തിന് പ്രാണവായുവും പോഷകങ്ങളും സ്ഥിരമായി ലഭ്യമാകണം. തലച്ചോറിലെ പ്രാണവായു സമ്പുഷ്ടത വിലയിരുത്താൻ നിരവധി മാർഗ്ഗങ്ങളുണ്ട് അവയിൽ പ്രാദേശികമായി കലകളുടെ പ്രാണവായു സമ്പുഷ്ടത തുടർച്ചയായി ശരീരത്തിൽ കടക്കാതെ രോഗിയുടെ നെറ്റിയുടെ ഇരുവശത്തും ഘടിപ്പിക്കുന്ന ഇലക്ട്രോഡുകളുടെ സഹായത്താൽ നിരീക്ഷിക്കുന്ന സാങ്കേതികവിദ്യയാണ് എൻഐആർഎസ്.

**താങ്കൾ പങ്കെടുക്കുകയാണെങ്കിൽ എന്തു ചെയ്യണം?**

ശസ്ത്രക്രിയയുടെ തലേദിവസം മയക്കലിനുവുമുള്ള പതിവ് പരിശോധനകൾ നടത്തും. ശസ്ത്രക്രിയാദിവസം താങ്കളെ ശസ്ത്രക്രിയാമുറിയിലോ ഇന്റർവെൻഷണൽ റോഡിയോളജി മുറിയിലോ പ്രവേശിപ്പിക്കും.. താങ്കളുടെ ഹൃദയതാളം, രക്തസമ്മർദ്ദം, പ്രാണവായു സമ്പുഷ്ടതയുടെ നില എന്നിവ ശരീരത്തിൽ പ്രവേശിക്കാതെ നിരീക്ഷിക്കുന്ന നിരീക്ഷണ ഉപകരണങ്ങൾ ഘടിപ്പിക്കും. പ്രാദേശികമായ മയക്കലിനുവിധേയമായി മരുന്നും ദ്രാവകങ്ങളും നൽകാൻ ഒരു 18 ജി ക്യൂഴൽ കൈയിൽ കടത്തും.

നെറ്റിയുടെ ഇരുവശങ്ങളിൽ എൻഐആർഎസ് ഇലക്ട്രോഡുകൾ ഘടിപ്പിക്കുകയും അടിസ്ഥാന മൂല്യങ്ങൾ രേഖപ്പെടുത്തും. രക്തക്കുഴലിലൂടെ കുത്തിവെച്ച് മയക്കൽ മരുന്ന് നൽകും. അതിനുശേഷം താങ്കൾ പൂർണ്ണമായും മയങ്ങി നിശ്ചലമാകുമ്പോൾ താങ്കളിൽ കൃത്രിമ ശ്വാസനയന്ത്രം ഘടിപ്പിക്കും. അതിനുശേഷം ശസ്ത്രക്രിയ പുരോഗമിക്കുന്നതിനനുസരിച്ച് എൻഐആർഎസ് മൂല്യങ്ങൾ തുടർച്ചയായി നീരീക്ഷിക്കും. ഓരോ മുറിവുണ്ടാക്കുമ്പോഴും ശേഷവും ശസ്ത്രക്രിയയ്ക്ക് ശേഷം 24 മണിക്കൂറും എൻഐആർഎസ് മൂല്യങ്ങൾ രേഖപ്പെടുത്തും.

**എൻഐആർഎസിന് പാർശ്വഫലങ്ങളെന്തെങ്കിലും ഉണ്ടോ?**

എൻഐആർഎസ് ശരീരത്തിൽ പ്രവേശിക്കാത്ത സങ്കേതമാകയാൽ അപായമൊന്നുമില്ല. ഇതുചെയ്യുന്നതിൽ ദോഷകരമായ സംഭവങ്ങളൊന്നുമില്ല.

**പഠനമാരംഭിച്ചശേഷംതാങ്കൾക്ക് പിൻമാറാനാകുമോ?**

താങ്കളുടെ പഠനത്തിലെ പങ്കാളിത്തം തികച്ചും സ്വമേധയായുള്ളതും സമ്മതം പിൻവലിക്കാൻ ഏതു സമയത്തും താങ്കൾക്ക് സ്വാതന്ത്ര്യമുള്ളതുമാണ്. താങ്കളുടേതല്ലാത്ത ചെയ്താലും ഈ ആശുപത്രിയിലെ താങ്കളുടെ പതിവ് ചികിത്സയെ ഒരു തരത്തിലും ബാധിക്കില്ല. ഒപ്പം, എന്തെങ്കിലും പാർശ്വഫലങ്ങളോ പ്രശ്നങ്ങളോ ഉണ്ടായാൽ പഠനം നിർത്തുകയും താങ്കളെ ചികിത്സിക്കുകയും ചെയ്യും.

**ഈ പരിശോധനയ്ക്ക് താങ്കൾ പണം നൽകണോ?**

ഇവ ശസ്ത്രക്രിയയിൽ മയക്കൽ നടപടികൾക്കുപയോഗിക്കുന്നവയാണ്, ആകയാൽ അധികമായി ഒരു ചിലവും ഉണ്ടാകില്ല.

**താങ്കളുടെ വ്യക്തിപരമായ വിവരങ്ങൾ രഹസ്യമായിരിക്കുമോ?**

താങ്കളുടെ വ്യക്തിപരമായ വിവരങ്ങൾ രഹസ്യമായിരിക്കും. ഈ പഠനം ഫലങ്ങൾ അക്കാദമിക് ഗവേഷണത്തിന്റെ ഭാഗമായി ഉപയോഗിക്കുകയും ഒരു വൈദ്യശാസ്ത്ര ജേർണലിൽ പ്രസിദ്ധീകരണത്തിനയക്കുകയും ചെയ്യും. പക്ഷേ താങ്കളെ പേരുകൊണ്ട് പ്രസിദ്ധീകരണത്തിലോ പ്രദർശനത്തിലോ ഒരിടത്തും തിരിച്ചറിയാനാകില്ല. എന്നിരുന്നാലും, താങ്കൾ പഠനത്തിൽ പങ്കെടുക്കാൻ തീരുമാനിച്ചാൽ താങ്കളുടെ ചികിത്സാരേഖകൾ പഠനവുമായി ബന്ധപ്പെട്ടവർ താങ്കളുടെ വീണ്ടുമുള്ള സമ്മതമില്ലാതെ അവലോകനം ചെയ്തേക്കാം.

താങ്കൾക്ക് കൂടുതൽ ചോദ്യങ്ങളുണ്ടെങ്കിൽ ദയവായി ചോദിക്കുക, ഡോ. ജിതുമോൾ തങ്കം തോമസ് (പ്രധാന ഗവേഷക) മൊബൈൽ നമ്പർ 963209455 ഇമെയിൽ [drjithu88@gmail.com](mailto:drjithu88@gmail.com)

പഠനത്തിന്റെ നൈതീക അനുവാദവുമായി ബന്ധപ്പെട്ട വിശദീകരണങ്ങൾക്ക് ഡോ. മാലാരാമനാഥൻ, മെമ്പർ സെക്രട്ടറി, SCTIMST IEC, അഡീഷണൽ പ്രൊഫസർ/ ഫോൺ 2524234 ഇമെയിൽ [iec.mem.sec@sctimst.ac.in](mailto:iec.mem.sec@sctimst.ac.in)

## MODIFIED RANKIN SCALE

<b>SCORE</b>	<b>DESCRIPTION</b>
0	No symptoms at all
1	No significant disability despite symptoms, able to carry out all usual activities and duties
2	Slight Disability, Unable to carry out previous activities, but able to look after all affairs without assistance
3	Moderate Disability requiring some help, but able to walk without assistance
4	Moderately severe Disability, unable to walk without assistance and unable to attend to own bodily needs without assistance
5	Severe Disability, Bedridden, incontinent and requiring constant nursing care and attention
6	Dead



**Technical Advisory Committee (Clinical Studies)**  
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES & TECHNOLOGY  
THIRUVANANTHAPURAM – 695011, INDIA

**TAC Registration No: SCT-/S/2020/1108**

**Date: 27.07.2020**

**Project title:** MONITORING OF CEREBRAL OXYGENATION TRENDS WITH NEAR INFRARED SPECTROSCOPY IN PATIENTS UNDERGOING THERAPEUTIC MANAGEMENT OF SUPRATENTORIAL ARTERIO-VEINOUS MALFORMATION AND EVALUATING ITS EFFICACY IN DETECTING PERIPROCEDURAL COMPLICATIONS AND THERAPEUTIC PROGNOSTICATION-AN OBSERVATIONAL PILOT STUDY

<b>Principal Investigator:</b> Dr. Jithumol Thankam Thomas, Senior Resident (DM Neuroanaesthesia), Division of Neuro-anaesthesiology and neurocritical care, Department of Anaesthesiology, SCTIMST Degree: MBBS, MD (Anaesthesiology), DNB
<b>Co-Principal Investigator(s):</b> Dr Ajay Prasad Hrishi, Associate Professor, Division of Neuro-anaesthesiology and neurocritical care, Department of Anaesthesiology, SCTIMST Degree: MBBS, MD (Anaesthesiology), DNB,DM(Neuroanaesthesia)
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Dr Manikandan Sethuraman, Professor, In-charge of Division of Neuro-anaesthesiology and neurocritical care, Department of Anaesthesiology, SCTIMST Degree: MD, PDCC (Neuro-anesthesiology)
<b>Co- Investigator(s):</b> Dr Mathew Abraham, Professor and Head, Department of Neurosurgery, SCTIMST Degree: MS, Mch(Neurosurgery), FRCS(Edin)
Dr Jayadevan E R, Additional Professor, Dept of Imaging Sciences and Interventional Radiology, SCTIMST Degree: MD, DNB, DM(Neuroradiology)

**Members who participated in the TAC meeting on 20/06/2020**

Dr Harikrishnan S (Chairman)

Dr Manikandan S

Dr Narayanan Namboodiri

Dr Jayadevan E R

Dr Sylaja P N

Dr Ramshekhar N Menon

Dr Unnikrishnan K P

Dr Syam K

Dr Sanjay G

Dr Deepti A N

Dr Sabarinath Menon

Dr Jayanand Sudhir B

Dr Srinivas G (Member Secretary)

Dr Sabarinath Menon, Dr Ramshekhar N Menon, Dr Sylaja P N, Dr Deepti A N, Dr Manikandan S, Dr Narayanan Namboodiri, Dr Srinivas G, Dr Sanjay G, Dr Harikrishnan S, Dr Unnikrishnan K P, Dr Syam K and Dr Jayadevan E R stayed away from the proceedings when the projects in which they are involved as investigator were discussed (#1072,1087, 1089, 1092, 1093, 1095, 1096, 1097, 1098, 1099, 1100, 1101, 1103, 1107, 1108, 1111, 1113, 1114, 1116, 1118, 1119, 1120, 1121, 1122, 1123, 1127, 1129, 1130)

**Risk Classification of the project (Minimum/ Moderate/ High):** Minimum

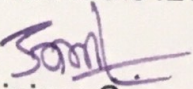
**Requirement of DSMB:** No

**Recommended members of DSMB:** Not applicable

**Recommendations of TAC:**

Recommended for consideration of IEC in the light of the responses received from the investigator

The PI may note that there can be no additions / alterations in the documents approved by TAC when they are submitted to the IEC.

  
Dr Srinivas G

**MEMBER SECRETARY**

**TAC (Clinical Studies)**

**SCTIMST**

**Note for IEC**

Copy of the investigator's responses to questions/suggestions from TAC is attached (Appendix-1).

## Appendix-1

The investigators are planning to do an observational pilot study evaluating the changes in cerebral oxygen saturation in patients undergoing arteriovenous malformation(AVM) resection surgeries and embolization procedures using near infrared spectroscopy( NIRS)monitor. They hypothesize that NIRS reflects cerebral perfusion and helps in timely detection of cerebral ischaemia and/or cerebral hyperemia and thereby improve outcomes in this subset of patients. The main objective is to study the correlation between intraoperative changes in regional cerebral oximetry and postoperative complications such as cerebral ischaemia, cerebral edema, haemorrhage and seizures. They are also plan to study the effect of post procedure induced hypotension on NIRS values. Design: Prospective observational pilot study design with a reasonable sample size and the research methodology are appropriate. Two groups of patients are recruited: Group I – Patients undergoing surgical resection of AVM (R), Group II – Patients undergoing neurointerventional procedure for embolisation of AVM (E). Change in NIRS value from baseline (rSO<sub>2</sub>) and Postexcision/pre excision ratio (P-P) will be taken for analysis. Please verify the position of NIRS??  
Not clear

**Answer:** The NIRS electrodes will be placed on the forehead bilaterally, midway between the hairline and each eyebrow, which is the standard site as per the manufacture's instructions. I have highlighted the correction in the revised documents.

MEMBER SECRETARY  
TAC (Clinical Studies)  
SCIENTIST



श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेंद्रम - 695 011, केरल, भारत  
**SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY**  
TRIVANDRUM - 695 011, KERALA, INDIA  
(एक राष्ट्रीय महत्व का संस्थान, विज्ञान एवं प्रौद्योगिकी विभाग, भारत सरकार)  
(An Institution of National Importance, Department of Science and Technology, Government of India)  
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ई-मेल/E-mail: sct@sctimst.ac.in वेबसाइट/Website: www.sctimst.ac.in



## Institutional Ethics Committee

(IEC Regn No. ECR/189/Inst/KL/2013/RR-16)

SCT/IEC/1593 /DECEMBER-2020

19.12.2020

**Dr. Jithumol Thankam Thomas**

Senior Resident

Division of Neuro-anaesthesiology and neurocritical care, Department of Anaesthesiology  
SCTIMST, Thiruvananthapuram

Dear Dr. Jithumol Thankam Thomas,

Thank you for submitting documents related to your proposal titled “**MONITORING OF CEREBRAL OXYGENATION TRENDS WITH NEAR INFRARED SPECTROSCOPY IN PATIENTS UNDERGOING THERAPEUTIC MANAGEMENT OF SUPRATENTORIAL ARTERIO-VEINUS MALFORMATION AND EVALUATING ITS EFFICACY IN DETECTING PERIPROCEDURAL COMPLICATIONS AND THERAPEUTIC PROGNOSTICATION-AN OBSERVATIONAL PILOT STUDY (IEC/1593)**” to the IEC for review.

### The following documents were reviewed:

1. Check list
2. Covering letter addressed to Chairman, IEC, SCTIMST dated 12.08.2020 forwarded by the HOD
3. TAC Approval with Comments and responses
4. Signed IEC Application
5. Study Proposal
6. Proforma
7. Consent form (English)
8. Consent form (Malayalam)
9. Patient Information sheet (English)
10. Patient Information sheet (Malayalam)
11. Signed CV of PI, Dr. Jithumol with TMC Registration number
12. Signed CV of Dr. Ajay Prasad Hrishu with TCMC Number
13. Signed CV of Dr. Ranganatha Praveen with KMC Number
14. Signed CV of Dr. Manikandan with TCMC Number
15. Signed CV of Dr. Mathew Abraham with TCMC Number
16. Signed CV of Dr. Jayadevan with TCMC Number

The following members of the Students Sub-Committee of the Institutional Ethics Committee participated in the discussions held between August 23-October 29, 2020 at the offices and residences of the members

SL. No.	Member Name	Highest Degree	Gender	Scientific /Non Scientific	Affiliation with Institution(s)
1.	Dr. R V G Menon	M Tech, PhD	Male	Lay Person (Chairman)	No
2.	Dr. Harikrishnan S	MD, DM (Cardiology) DNB (Cardiology)	Male	Clinician	Yes
3.	Dr. Kala Kesavan. P	MBBS, MD	Female	Basic Medical Scientist	No
4.	Smt. Sathi Nair	MA (English Literature)	Female	Lay Person	No
5.	Dr. Rema M. N	MD	Female	Basic Medical Scientist	No
6.	Dr. Christina George	MD Psychiatry	Female	Clinician	No
7.	Dr. Mala Ramanathan	PhD	Female	Social Scientist (Member Secretary)	Yes

### IEC Decision


The IEC approved the conduct of the study in the present form.

### Remarks:

The Institutional Ethics Committee expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent and asks to be provided a copy of the final report.

There was no member of the study team who participated in voting / decision making process. The ethics committee is organized and operated according to the requirements of Good Clinical Practice and the requirements of the Indian Council of Medical Research (ICMR).

Sincerely,



**Mala Ramanathan**

Member Secretary, IEC

# PLAGIARISM CHECK REPORT



## Document Information

Analyzed document	JTT V6.docx (D142512646)
Submitted	7/29/2022 11:16:00 AM
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Analysis address	kanmanis.sctims@analysis.arkund.com

## Sources included in the report

<b>W</b>	URL: <a href="https://www.science.gov/topicpages/c/cerebral+tissue+oxygenation">https://www.science.gov/topicpages/c/cerebral+tissue+oxygenation</a> Fetched: 5/7/2022 10:12:19 AM	 5
<b>W</b>	URL: <a href="https://pure.uva.nl/ws/files/1651812/46999_pennings.pdf">https://pure.uva.nl/ws/files/1651812/46999_pennings.pdf</a> Fetched: 7/30/2020 3:49:11 AM	 5
<b>W</b>	URL: <a href="https://www.mdpi.com/1424-8220/21/5/1586/pdf">https://www.mdpi.com/1424-8220/21/5/1586/pdf</a> Fetched: 4/24/2021 9:07:46 PM	 6
<b>W</b>	URL: <a href="https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4237713/">https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4237713/</a> Fetched: 4/26/2021 8:45:35 PM	 3
<b>W</b>	URL: <a href="https://core.ac.uk/download/pdf/81670201.pdf">https://core.ac.uk/download/pdf/81670201.pdf</a> Fetched: 7/29/2022 6:38:30 AM	 3
<b>W</b>	URL: <a href="https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8466732/">https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8466732/</a> Fetched: 12/14/2021 8:10:33 AM	 1



## MASTER CHART

Pt No	Age	Sex	Presentation	Diagnosis	Preop seizures	Procedure	Size of Nidus	SM grade		Preop Hb	Anesthesia
Group A											
1	19	M	Seizures	Residual Right PO AVM		Resection	11*10*9	I		14.2	inhalation
2	23	F	Headache	Left FT AVM		Resection	13*12*13MM	II		11.4	inhalation
3	45	F	Seizures	LEFT Insula AVM		Resection	11*9*7.6	III		11.6	inhalation
4	17	M	Seizures	Right Parietal AVM		Resection	12*14*9	II		15.8	inhalation
5	21	F	Hemorraghe	Right basi frontal AVM		Resection	20*18*18	I		11.4	inhalational
6	26	M	Hemorraghe	Right frontal AVM		Resection	19*24*20	I		15.9	inhalational
7	18	M	Seizures	left Parietal AVM	present	Resection	12*10*18	II		12.6	Inhalational
8	20	M	Headache	Right frontal AVM		Resection	10*9*8	I		17.6	inhalational
9	29	M	Headache	left Parietal AVM		Resection	14*12*10	II		16	Inhalational
10	17	M	Hemorraghe	Left FP AVM		Resection	16*14*21	II		15.1	inhalation
Group B											
1	51	M	Headache	Left insularAVM	present	Resection	22*16*23	II		12.2	inhalation
2	19	M	Seizures	Right PO AVM		Resection	28*10*20	III	Residual AVM	10.6	inhalation
3	55	M	Hemorraghe	RIGHTFT AVM		Resection	12*32*14	II		14.4	inhalation
4	25	M	Hemorraghe	Right Parietal AVM	Present	Resection	30*18*11	III		14	inhalational
5	27	M	Seizures,	Left post Temporal AVM		Resection	26*21*22	III	Micro residual nidus(4mm)	17	Inhalational



					DBP						MAP												EtCO2					
N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6		N2	N3	N4	N5	N6	N1	N2	N3	N4	N5	N6
102	104	102	98	96	75	62	58	58	52	53	87	76	73	73	68	79	12	14	16	17	14	15	32	33	33	32	32	34
110	110	108	106	100	76	76	80	67	60	50	84	87	90	81	75	67	8	6	7	4	4	7	29	30	30	32	32	30
110	106	113	112	100	92	74	60	64	68	55	100	83	80	89	85	73	12	12	10	9	10	12	34	31	28	28	28	26
117	123	116	120	120	79	82	85	77	79	81	93	96	100	93	95	97	9	8	8	7	8	8	28	30	27	27	27	27
90	94	100	89	99	61	54	51	57	55	60	75	68	67	71	78	74	13	13	11	18	18	16	28	32	31	32	31	31
94	90	107	96	103	71	53	41	61	54	94	81	71	60	82	72	97	12	10	8	8	4	10	29	39	29	29	30	30
106	123	122	118	125	72	55	68	68	64	69	86	66	84	84	81	89	14	10	8	7	6	6	30	34	31	30	26	28
114	113	110	121	109	73	70	72	80	77	69	90	84	85	92	92	83	8	10	10	8	8	9	28	37	32	32	33	32
96	104	114	105	97	64	52	51	61	58	53	100	65	69	80	73	64	18	17	16	17	18	13	28	33	29	30	29	29
102	108	103	108	103	74	71	62	63	69	63	89	81	77	76	82	76	8	10	12	11	17	14	36	32	32	30	32	30
115	106	102	99	102	60	69	63	60	60	68	74	81	82	78	69	71	8	4	13	14	15	12	31	30	28	28	28	32
120	122	118	112	128	62	72	74	70	80	70	68	82	90	86	70	89	10	12	15	15	12	10	38	32	32	31	30	34
125	118	113	128	116	82	67	68	66	74	77	98	87	85	86	70	80	8	9	5	5	4	5	31	29	29	30	31	32
94	100	96	94	99	96	45	57	59	58	66	104	58	70	71	68	72	18	9	15	14	11	10	30	30	32	34	32	
90	96	96	99	109	85	51	56	56	57	69	94	64	71	71	65	79	12	11	15	17	13	12	26	32	32	32	32	33

Spo2							Ipsi NIRS													$\Delta R_{so2}$				
	N1	N2	N3	N4	N5	N6		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12		P1	P2	P3	P4
100	100	100	100	100	100	61	70	58	57	67	65	64	65	69	70	67	63	-8	6	-12	-14			
100	100	100	100	100	100	68	70	74	72	70	68	72	74	75	74	72	74	8	10	14	12			
100	100	100	100	100	100	74	75	76	78	75	76	74	75	73	73	75	73	22	24	26	28			
100	100	100	100	100	100	73	70	87	86	89	84	83	74	71	75	73	70	-15	-8	1	0			
100	100	100	100	100	100	85	88	88	87	88	86	88	84	85	84	84	85	21	26	26	24			
100	100	100	100	100	100	68	73	82	82	85	85	81	85	81	78	82	84	-4	3	15	15			
100	100	100	100	100	100	67	72	68	67	67	64	66	66	68	68	69	68	10	16	11	10			
100	100	100	100	100	100	68	74	78	78	80	85	85	82	80	75	80	75	-6	2	8	8			
100	100	100	100	100	100	63	74	76	71	74	78	72	70	68	72	72	68	-4	10	12	5			
100	100	100	100	100	100	78	80	85	80	81	80	78	80	82	84	85	84	-1	1	4	1			
100	100	100	100	100	100	Nc- 66	65	55	59	55	51	66	66	65	64	65	64	-2	-3	-12	-10			
100	100	100	100	100	100	78	77	83	70	74	78	82	81	80	78	80	78	-8	-9	-2	-12			
100	100	100	100	100	100	58	60	61	64	55	56	58	58	57	57	57	58	-28	-32	-31	-30			
100	100	100	100	100	100	81	80	81	79	68	74	76	72	78	80	84	74	27	25	27	23			
100	100	100	100	100	100	68	58	58	60	60	67	71	68	67	62	62	63	-17	-29	-29	-27			

								Contr NIRS													$\Delta R_{so2}$ Contr			
P5	P6	P7	P8	P9	P10	P11	P12	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P1	P2	P3	P4	
0	-2	-3	-2	5	6	0	-5	69	77	64	63	73	73	72	69	77	77	71	69	15	28	7	5	
10	8	12	14	15	14	15	14	74	70	71	72	68	68	69	70	72	72			28	22	22	24	
24	26	22	24	20	20	21	22	62	64	65	66	67	68	57	50	50				-2	0	2	4	
3	-2	-3	-14	-17	-13	-15	-17	68	80	83	82	86	91	82	71	68	74	72	73	-15	0	4	3	
26	23	26	19	21	19	21	19	75	76	72	72	75	75	74	70	70	71			1	3	-3	-3	
20	20	14	20	14	10	15	12	72	86	95	92	94	88	88	88	84	80	79	82	3	23	36	31	
10	5	8	10	12	12	12	10	12	14	4	6	7	-6	-1	0	1	6			12	14	4	6	
12	14	14	12	12	4	5	10	80	82	78	85	81	82	85	88	82	80			1	3	-1	4	
10	14	6	4	1	6	1	6	74	80	85	82	75	77	74	78	78	80			3	14	18	18	
2	1	-1	2	3	6	5	6	68	71	74	74	72	70	68	68	70	68	69		0	3	5	5	
-12	-14	-2	-2	-3	-4	-3	-4	72	70	66	65	64	64	69	69	69	69	69	69	3	1	-2	-3	
-12	-8	-2	-4	-6	-8	-6	-8	65	67	68	65	62	65	60	65	62	65			10	40	15	2	
-38	-38	-34	-34	-35	-35	-34	-35	63	61	61	62	57	57	62	61	63	63			-4	-13	-13	-13	
27	16	18	14	22	26	30	16	71	71	71	69	68	70	68	66	72	70	80	75	13	13	13	10	
-27	-18	-13	-17	-18	-24	-18	-24	67	58	62	61	61	68	62	70	68	63			-20	-25	-25	-27	

								SBP												
P5	P6	P7	P8	P9	P10	P11	P12	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	
22	22	20	15	28	28	20	15	102	122	111	106	90	98	99	102	90	90	100	108	
18	18	20	22	24	24	23	24	110	112	108	102	105	106	115	107	100	106	102	106	
6	8	-11	-20	-20	-20	-21	-24	-20	108	110	112	115	122	110	108	102	108	102	108	
8	14	3	-11	-15	-8	-10	-9	119	124	116	115	112	112	113	114	117	117	116	119	
1	1	0	-6	-6	-4	-4	-5	104	112	109	102	97	97	102	104	102	99	102	99	
34	27	26	26	20	14	13	17	108	112	120	110	110	93	97	97	102	104	100	99	
7	-6	-1	0	1	6	6	1	102	95	118	119	118	93	106	109	110	116	110	116	
2	3	4	7	3	1	1	3	112	110	103	102	110	115	108	110	104	102	105	102	
5	8	3	9	9	12	12	11	106	110	102	104	103	112	108	110	102	105	102	105	
3	2	0	0	2	0	1	1	112	104	103	102	98	101	108	102	103	101	110	101	
-4	-4	0	0	0	0	0	0	110	108	96	96	98	101	102	100	103	99	107	108	
4	10	2	10	4	10	6	10	117	120	127	102	108	112	114	112	114	112	112	114	
-19	-19	-11	-13	-10	-10	-12	-10	115	129	120	120	118	126	115	115	128	118	126	117	
10	12	8	6	15	11	26	19	108	95	98	104	90	106	94	97	94	102	108	100	
-27	-19	-25	-14	-19	-25	-24	-26	95	97	102	100	100	114	102	105	98	103	101	97	

DBP													MAP						HR											
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P1	P2	P3	P4	P5	P5	P7	P8	P9	P10	P11	P12	P1	P2	P3	P4	P5	P6
56	63	68	62	56	63	65	63	62	60	57	50	71	83	82	77	67	75	76	76	71	70	78	69	65	102	82	104	94	84	
68	65	62	64	64	60	78	62	58	68	67	68	64	68	77	77	78	75	90	77	72	75	72	75	78	79	68	65	66	67	
55	60	60	64	58	74	86	74	70	72	70	72	78	80	84	85	84	88	80	80	78	79	77	73	72	80	72	74	74	71	
68	91	85	85	60	61	62	63	68	67	67	67	85	105	97	95	70	78	78	81	84	84	84	83	57	59	77	77	78	72	
60	66	62	61	54	55	57	51	58	56	58	56	75	76	73	74	63	70	66	63	72	70	70	72	60	62	58	64	68	70	
69	66	67	65	64	57	54	54	57	51	54	56	78	76	76	77	75	65	63	63	66	63	65	70	72	70	90	90	89	67	
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60	60	68	70	60	61	69	62	64	62	65	64	77	75	80	81	73	74	82	75	77	75	71	70	82	80	81	70	70	74	
64	63	62	64	67	67	65	65	63	65	64	64	83	82	75	78	76	77	77	74	73	71	78	72	86	87	82	75	78	76	
69	71	65	59	60	70	68	88	62	64	65	65	82	85	85	72	72	80	81	80	74	78	74	71	86	93	91	113	110	112	
64	71	72	70	68	74	65	55	58	68	68	67	82	90	90	88	81	82	70	68	73	81	73	72	71	71	76	82	85	90	
55	49	51	53	47	60	60	64	60	66	59	59	73	64	68	70	62	76	70	70	64	70	76	67	56	56	56	54	63	70	
63	53	57	60	60	64	53	56	54	62	64	62	72	64	66	71	71	74	69	72	68	72	74	72	86	82	88	85	87	87	

						Spo2													Postop complication	Time of complication	mRSScore	Intraop Fluid in litres	Blood product transfusion
P7	P8	P9	P10	P11	P12	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12						
89	86	96	94	100	104	100	100	100	100	100	100	100	100	100	100	100	100			1	3		
76	72	70	80	78	80	100	100	100	100	100	100	100	100	100	100	100	100			0	2.2		
70	72	73	76	77	76	100	100	100	100	100	100	100	100	100	100	100	100			1	2.4		
74	72	62	56	55	77	100	100	100	100	100	100	100	100	100	100	100	100			0	2.4		
72	68	70	70	71	69	100	100	100	100	100	100	100	100	100	100	100	100			0	2.8		
73	68	70	72	80	82	100	100	100	100	100	100	100	100	100	100	100	100			0	2.5		
87	96	90	94	92	90	100	100	100	100	100	100	100	100	100	100	100	100			0	2.4		
80	80	78	94	91	90	100	100	100	100	100	100	100	100	100	100	100	100			1	2.5		
90	96	82	78	80	81	100	100	100	100	100	100	100	100	100	100	100	100			1	2.5		
75	76	72	71	74	76	100	100	100	100	100	100	100	100	100	100	100	100			1	2.8		
77	77	76	76	77	80	100	100	100	100	100	100	100	100	100	100	100	100	Postop EDH,Seizures-Conservative	P1	2	3.5	500 ml	
102	104	105	106	112	108	100	100	100	100	100	100	100	100	100	100			Seizures,Reintubation after 3hours of extubation.Extubated after 24 hrs/prolonged ventilation	P4	1	2.8	235 ml	
98	97	93	85	90	89	100	100	100	100	100	100	100	100	100	100			Venous infarct,Grade 3 weakness ,seizures	P1	3	3.1	255	
72	68	72	81	75	75	100	100	100	100	100	100	100	100	100	100	100	100	Seizures,extubated after 48 hrs/prolonged ventilation	P5	2	2.65	250 ml	
84	90	82	86	99	101	100	100	100	100	100	100	100	100	100	100			Cerebral edema,2 episodes of seizures,extubated after 48 hrs/prolonged ventilation	P2	2	3.4	500	



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