

Anesthesia Management in Patients with Moyamoya Disease with Superficial Temporal Artery–Middle Cerebral Artery Bypass: Case Report

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Abstract

Moyamoya Disease (MMD) is a rare unknown disease that causes occlusion of the blood vessels of the brain in adults and children. There are several methods of operation that can be used for therapy, such as direct bypass and indirect bypass. Direct bypass is a method to connect the branches of the external carotid artery, usually the superficial temporal artery (STA), to the branching of the internal carotid artery, generally the Middle Cerebral Artery. It's potentially created several problems such as secondary brain injury and changes in hemodynamic. We use general anesthesia based on neuroanesthesia concepts to protect brain perfusion and maintain the patient's hemodynamic stability. In this patient, induction was carried out using remifentanyl TCI Minto mode 4-6 ng/ml, Propofol TCI Schneider target effect 4–6 mcg/ml and Rocuronium 40 mg IV. We also add SCALP Block with Bupivacaine 0.25% volume of 2–3 ml. Before induction, an arterial line was installed on the right radial artery to determine hemodynamic changes, to protect cerebral perfusion pressure. The patient was stable during the operation and extubated immediately after the surgery. The patient returned to his initial state of consciousness and was admitted to the ICU for 48 hours.

Keywords: General anesthesia, moyamoya disease, MMD, STA – MCA bypass, non-hemorrhagic stroke, cerebrovascular occlusion, idiopathic ICA occlusion

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Introduction

The Japanese Ministry of Health defines moyamoya disease (MMD) as occlusion or stenosis of the internal carotid artery bilaterally or unilaterally artery accompanied by the branching of new blood vessels at the base of the brain. Stenosis begins at the terminal branch of the internal carotid artery and progresses progressively to the anterior middle and posterior cerebral arteries.¹ Stenosis will cause the formation of collateral blood vessels from the base of the brain which forms a picture like a wisp of smoke on angiography. In Japanese, wisp of smoke means moyamoya. Patients with MMD have clinical symptoms such as recurrent ischemic strokes, seizures, headaches,

intellectual decline, and in some pediatric cases intracranial hemorrhage. The diagnosis of MMD is confirmed using MRI, CT and Angiography. MMD therapy aims to revascularize parts of the brain experiencing ischemia.¹ There are several surgical methods that can be used, such as direct bypass and indirect bypass.^{1,2} Direct bypass is a method of connecting a branch from the external carotid artery, usually the superficial temporal artery (STA), to a branch from the internal carotid artery, generally the middle cerebral artery. Indirect bypass aims to improve collateral blood flow through angiogenesis by making contact between highly vascularized extracranial tissue and meninges, such as encephalo-duro-arterio-synangiosis, where the STA will be connected to the dura, or encephalo-myo-synangiosis, where

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the temporal muscle is placed above brain surface.² This patient underwent a direct bypass, namely STA–MCA bypass which connects the superficial temporal artery with the middle cerebral artery. The operation began with ultrasound on the superior temporal artery to look for blood vessels that can be used for donors. STA – MCA bypass is a process to connecting STA branches connected to MCA.^{2,3} Anesthesia management in this patient pays attention to neuroanesthesia principles considering the changes in hemodynamic during clipping and augmentation process while maintaining the cerebral perfusion.⁴ Arterial Line was installed on the right radial artery for this purpose to determine changes in blood pressure during the procedure.⁵ By clamping the arteries there were potential to change mean arterial pressure (MAP) and therefore affecting cerebral perfusion pressure (CPP).⁶ Analgesics were given using remifentanyl TCI Mode Minto 4 – 6 ng/mL and sedation agent propofol TCI Mode Schneider target effect 4–6 mcg/ml, with muscle relaxant rocuronium 40 mg IV. Intubation was carried out with a videolaryngoscope and the addition of xylocaine spray to the oropharyngeal area to blunt sympathetic stimulation during intubation. Meanwhile, the use of a videolaryngoscope was aimed to simplify the intubation process and avoid intubation failure which has the potential to result in sympathetic stimulation in the patient.⁷ A Non-kinking endotracheal tube (ETT) measuring 7.5 mm was installed, with an ETT depth of 21 cm from the edge of the patient's outer lips. The ventilation was maintained with compressed air: oxygen and sevoflurane <1 MAC ventilator machine with low flow anesthesia 0.25 l/min, by maintaining pH levels of 7.35 – 7.45, pCO₂ 35 – 45, and pO₂ 100 – 200. Then we added bilateral SCALP block to enhance analgesia, and central venous catheter (CVC) to provide access to post-operative nutrition, measure the adequacy of fluid volume, and as therapeutic access for the patient.⁸ Nimodipine was administered when augmenting STA to MCA which aims to prevent post-procedure cerebral blood vessel vasospasm.⁹ The anesthesia lasted 9 hours 15 minutes and the operation lasted 7 hours 15 minutes. This patient was hemodynamically stable during surgery and after surgery, extubation was carried out immediately

and the patient admitted to the ICU after surgery.

Case Report

Anamnesis

A 54 year old female patient came for planned STA-MCA Bypass surgery. The patient was conscious and appeared calm but lack of contact. The patient was said to have difficulty communicating, able to follow simple commands, but unable to answer questions. Lack of eye contact, patient responded to opening eyes with touch. The patient's daily activities are currently assisted by the patient's family. History of previous illness on April 23, 2020, the patient first experienced a SNH attack with complaints of weakness in right side extremities with slurred speech. At that time he received treatment for 5 days and recovered with good consciousness and improved clinically. On October 21, 2021, the patient experienced a second SNH attack, with symptoms of decreased consciousness and slurred speech, he underwent treatment for 7 days. November 25, 2023 the patient experienced recurrent SNH Sinistra with suspected hypoperfusion and thrombus in left side hemisphere with symptoms of decreased consciousness, the family said at that time the patient tended not to respond when awakened. April 28, 2024, the patient experienced a loss of consciousness again accompanied by symptoms of increased intracranial pressure in the form of headaches and seizures. Patient was said to respond more slowly than before the attack. Cognitive function was said to be declined. June 05, 2024, the patient was said to experience decreased consciousness as the patient started to fall asleep more often, he could be awakened but after that he fell asleep again. Complaints accompanied by a history of recurrent seizures; the last recurrence of seizures was 1 month ago with seizures describes as jerking all of the extremities. The seizure was said to last 1 minute. Currently the patient is being treated with Acetosal 80 mg every 24 hours, donepezil 10 mg every 24 hours, carbamazepine 200 mg every 8 hours intraorally, amlodipine 10 mg every 24 hours intraorally, simvastatin 20 mg every 24 hours intraorally. There were no histories of food and drugs allergy.

The patient's history of surgery were 2 times, on September 12, 2021 at Prof. Ngoerah Hospital, for soft tissue swelling biopsy. June 28, 2024 at Prof Ngoerah General Hospital undergoing DSA. The patient was known to have suffered from hypertension since 2022, currently on amlodipine 10 mg but did not take medication regularly. The patient was also known to have Type II DM since 11 years ago with therapy with metformin 500 mg every 24 hours PO, glibenclamide 2.5 mg every 24 hours PO. Currently the patient is no longer working, and is only able to carry out light physical activity with assistance, without complaints of shortness of breath or chest pain.

Physical Examinations

The patient weighs 50 kg, height 150 cm, body mass index 22.22 kg/m². During the examination, we found that the patient GCS E3V4M5 with bradyphrenia or slowed cognitive impairment, pupillary isochore 3 mm/3mm, pupillary reflex +/+, motoric 2222/4444 // 2222/4444 there was the impression of supranuclear paresis of nerves VII et sinistra found positive. On examination, the patient's respiration within normal limits with a respiratory frequency of 18 times/minute, vesicular breath sounds in both lung fields, rhonchi and wheezing were absent, peripheral oxygen saturation was 99% on room air. Blood pressure 160/80 mmHg with hypertension, pulse was 78 beats/minute, heart sounds 1 and 2 were single, regular, no murmurs, no gallops. Urogenital examination within normal limits and examination of the extremities showed that the capillary refill time was less than 2 seconds. The patient is currently known to be unable to carry out light activities such as taking care of himself, and is very dependent on the help of people around him with a Hachinski score of 14 leading to suspicion of vascular dementia.

Laboratory Examination Result

On a complete blood test, white blood cells was obtained 9.48 x 10³/μL (4.1–11.0); hemoglobin 13.7 g/dL, platelets 268 x 10³/μL, mean corpuscular volume 86.6 fL, mean corpuscular hemoglobin 29.1 pg, Mean corpuscular hemoglobin concentration 33.7 g/dL. With the examination of hemostasis

function test, prothrombin time was obtained 14 seconds, activated partial thromboplastin time 28.4 seconds, International Normalized Ratio 1.01. Patients with a history of type II Diabetes Mellitus with an HB-A1C 6.8%. A plain picture of thorax was obtained from the heart and lungs and there was no abnormality and there was thoracal spondylosis. On the ECG examination, sinus rhythm was obtained, with a heart rate of 80 x / minute, there was a picture of T inversion in V4-V5 I, AVL. In the CT Scan of the Head with contrast, a picture of encephalomalacia was found in the right semiovale centrum, right corona radiata, parietal lobe, temporal to right occipital. Chronic lacunar cerebral infarction pada corona radiata kiri dan capsula externa kiri. Perfusion Analysis finding: cerebral blood volume, cerebral blood flow, and mean transit time match core-penumbra infarct (irreversible) defects in the left right frontoparietal region and right occipital region, according to the right and left MCA territories of branches M1, M4, M5, M6. Small vessel ischemic changes in the pericornu of the right and left lateral ventricles. Observed multiple calcifications of the right frontal and parietal lobe cortical subcortical lobes, suspected cortical laminar necrosis. Age-related brain atrophy accompanied by hydrocephalus ex vacuo measurable Evans Index +/- 0.31. Hyper pneumatization of the right and left mastoids. Left ethmoidal sinusitis. Electroencephalogram examination was also carried out and currently showed clinical seizures in the form of focal aware clonic tonic seizures with EEG of the seizures originating from the right frontocentral area to support the diagnosis of epilepsy post stroke. The results of DSA found a typical picture of bilateral occlusion in communicating ICA with collaterality of posterior circulation with the image of "Puff of Smoke Sign" on the right and left MCA perforators impressing MMD.

Anesthesia and Surgical Management

The patient was concluded with physical status ASA III with complete SNH nervous and post-stroke epilepsy suspected vascular cognitive impairment, Moyamoya Disease with clinical patient when examined GCS E3V4M5 with impression of bradyphrenia accompanied by



Figure 1. Photo X-rays Thorax PA

cognitive impairment, with pupil isochore 3 mm/3 mm with impression of paresis at nervus VII et XII S supranuclear, motoric 2222/4444 // 2222/4444 hemiparesis spastic S grade 4 Babinski S+ history of seizure. On the CT Scan image, there are traces of encephalomalacia on the right semiovale centrum, right corona radiata, parietal, temporal to right occipital lobes. Chronic lacunar cerebral infarction in the left radiata corona and left externa capsula. In perfusion analysis: CBV, CBF, and MTT match corepenumbra infarct (irreversible) perfusion defects in the right left frontoparietal region and right occipital region, according to the territory of the right and left MCA branches M1, M4, M5, M6. Small vessel ischemic changes in the peri cornu of the right lateral ventricle of the left, multiple calcifications in the cortical subcortical frontal lobe and right parietal, suspected cortical laminar necrosis. Age-related brain atrophy accompanied by hydrocephalus ex vacuo with Evans Index +/- 0.31. With DSA found bilateral occlusion in communicating ICA with collateral of posterior circulation described as "Puff of Smoke Sign" on the right and left MCA perforators impressing MMD. Patients with suspected CAD with blood pressure 160/80 mmHg, heart rate 78 times/min, single heart sounds 1 and 2, regular, absent murmur, absent gallop with sinus rhythm electrocardiogram picture, pulse 80 x/min, with T inversion in V4-V5 I avL. In the thorax photo, there is an image of the heart and lungs without abnormalities with a CTR of 55%. A preliminary echocardiographic examination was

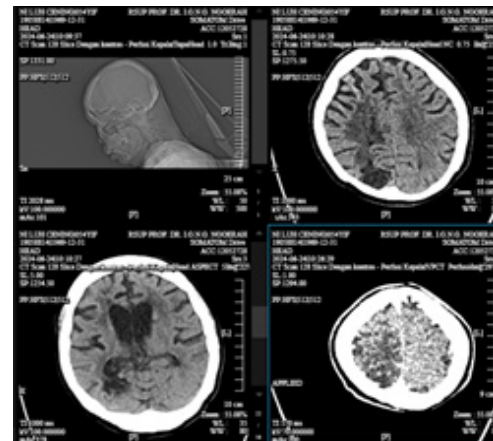


Figure 1. Photo X-rays Thorax PA

carried out with an Echo Preliminary image with a sense of normal cardiac chamber dimensions, LV concentric hypertrophy, LV systolic function 62.64% EF BP, diastolic function LV decreased grade I, Normal RV contractility, TAPSE 19 mm, global normokinetic, normal impression of valve. Patient also had the problem of Type II Diabetes Mellitus with current treatment: metformin 500 mg every 24 hours, glimepiride 2.5 mg every 24 hours, with blood sugar level 93 mg/dl and HbA1-c 6.8. The patient is currently not working and is only able to do light physical activity with the help of his family. In patients who have the potential to experience secondary brain injury, cushing, triad, hemorrhage, PONV, arrhythmias, hyper/hypotension, hypothermia, hypo/hyperglycemia

The patient prepared fasting solid food 8 hours preoperatively, and 2 hours of water. Approval of surgical procedures and anesthesia was taken from the patient's family. Installation of 2-line intravenous access, anesthesia and emergency drugs, warmer infusion, ETT Non Kinking, STATICS Anesthesia, long bougie, video laryngoscope, TCA devices, and syringe pump. Our patient was prepared with 4 bags of blood preparation and 2 bags of ready-to-use PRC, 5 bags of platelets, 5 bags of fresh frozen plasma, basal blood pressure checks at 22.00 WITA and blood pressure at 06.00 WITA, and morning blood sugar checks at 06.00 WITA. In the patient, an arterial line was attached, to check blood pressure precisely, measure hemodynamics, and a central

venous catheter. In this patient, inotropic drugs and vasoconstrictors and calcium beta blockers with nimodipine and nicardipine were also prepared. Patient arrived in the operating room, vital sign was measured with pre-induced blood pressure with blood pressure of 111/55 mmHg; heart rate 50 x/min, and respiration rate 12 x/min; with 100% room water saturation. The patient was positioned supine on the operating table, performed by installing an arterial line with an abocath 20 G, with 2% Lidocaine infiltration. Furthermore, the patient was given Remifentanyl TCI Minto mode 4-6 ng/mL and induction with Propofol TCI mode schneider target effect 4-6 mcg/ml, with an intubation facility using rocuronium 40 mg IV. Preoxygenation was carried out with 100% oxygen 8 lpm. With the patient's blood pressure before intubation was 111/55 mmHg, heart rate 50 x/min, and respiration 18–20 x/min, with PCO_2 30 – 31 cmH_2O . Intubation was carried out with a 7.5 mm Non-Kinking ETT, with an ETT depth of 21 cm from the edge of the patient's outer lip. Fixation was carried out with double tape and packing and bite block to prevent hypersalivation. The patient's blood pressure was observed to increase with blood

pressure of 124/57 mmHg, heart rate of 57 x/min, and oxygen saturation of 100%. In the next patient, CVC is installed on the D jugular vein with ultrasound guidance. Furthermore, bilateral SCALP Block was carried out by administering bupivacaine 0.25% volume of 2–3 ml to each nerve point N. supraorbital, N. supraocular, N. zygomaticotemporal, N. auriculotemporal, N. auricular major, N. lesser occipital.

In the patient, ventilation was carried out with a Perseus type ventilator with low flow FiO_2 90%, FG Flow 0.25, P max 25, tidal volume 350 ml, RR 10 x/min, Peep 4 and T Ins 2.0. For maintenance during surgery we give O_2 , Compressed water, Sevoflurane 0.3–0.5 MAC, Dexmedetomidine 0.2–0.7 mcg/kg/hour; Propofol TCI in schneider mode 3mcg/ml, and remifentanyl TCI 3-4ng/ml, and rocuronium 0.1 mg/kg body weigh every 30 minutes. The patient was stable with systolic blood pressure of 98 to 116 mmHg and diastolic 56 to 68 mmHg, heart rate 47 – 60 x/minute. Before the incision, a rocuronium was administered as much as 0.1 mg/kgBB. During the operation, Blood Gas Analysis was carried out with end tidal CO_2 reading in the ventilator machine when taken was 28, and the result obtained was pH 7.44; pCO_2 34 mmHg; pO_2 237 mmHg, Beecf -1.1 mmol/L (-2-2); HCO_3 23.10 mmol/L; SO_2 100%; TCO_2 24.10 mmol/L. From this, we concluded that the end tidal CO_2 detected in the machine and the actual pCO_2 have a difference in value of 6. So that the setting of the ventilator machine was changed again with the pCO_2 of the engine maintained at 32 mmHG (or about 38 mmHG at blood gas analysis).



Figure 4. Patient's Ventilator during Intubation



Figure 5. The Process of Opening the Duramater



Figure 6. Ventilator Setup

The patient was positioned with a headpin with head tilt slightly to the left. An examination with Doppler ultrasound was carried out to find the Proximal STA and distal STA, marking incisions and aseptic and antiseptic procedures were performed. Preliminary STA exposure was carried out and dissection was carried out to remove the surrounding tissue. STA searches were carried out distal and dissection of all branches of STA. Temporary clips of STA branches were then cut off to prepare for anastomosis with adventitious tunica dissection of the artery. An incision was made on the superior temporal line to open the temporal muscles and expose the bones. A 3-hole burrhole and craniotomy were performed. The patient was given mannitol 0.5 gr/KgBB/hour IV before opening the duramater. Dura exposure and sylvian fissure exposure were carried out. Arachnoid dissection to free M3 branches in the cortex. Temporally clips were made on both sides of the MCA and incisions are made according to the width of the STA. STA and MCA bypasses were carried out with end to side anastomose. It was carried out until all STA branches connect with MCA. Tests with an ICG to check for all patency of the bypass and arteries. Duraplasty was carried out, followed by cranioplasty, and paired with redon drain no 12, drain was fixated, and skin was sewed layer by layer. Clipping was carried out on the middle cerebral artery, blood pressure was 116 / 60 mmHg and heart rate 58 x / minute. Other treatments given to this patient were nimodipine 250 mg IV, tranexamic acid 1000 mg IV to prevent bleeding, and ondansetron 8 mg IV to prevent PONV in this patient. The operation lasted for 6 hours and 15 minutes, with a total anesthesia duration of 8 hours. At the



Figure 7. Clipping of the Meningeal Artery Branch Media with the Superior Temporalis Artery

end of the surgery time, in the end we awake extubation, the patient is well aware of returning to his initial consciousness, and after the surgery the patient was admitted in the ICU.

Discussion

Moyamoya in Japanese means cigarette smoke, moyamoya disease is a chronic disease, which is characterized by occlusion of the blood vessels of the brain involving bilateral stenosis at the terminals of the internal carotid arteries or the proximal part of the anterior cerebral arteries and middle cerebral arteries (MCAs).¹ The Japanese Ministry of Health divides MMD into 4 types: ischemic, hemorrhagic, epileptic and other types.¹ DSA on June 28, 2024, a typical cigarette smoke picture was found and was concluded to be moyamoya disease.¹ From the anamnesis of the family of the patient with a history of recurrent seizures and decreased cognitive function (bradyphrenia) and the existence of a neurological diagnosis, namely vascular dementia which is currently controlled with donepezil and carbamazepine. Donepezil is a -5,6-dimethoxy-indan-1-one monohydrochloride is a competitive non-competitive acetylcholinesterase inhibitor that functions to improve global function in patients with Alzheimer's disease and vascular dementia. Donepezil can penetrate the blood-brain barrier by binding to cations and increasing acetylcholine in the synaptic cleft.² Carbamazepine is a drug used for anti-seizures.³ In this patient, there was a history of recurrent seizures since May 6, 2024, the patient was given carbamazepine as much as 200 mg every 8 hours

orally. In the operating room, a blanket warmer is prepared and then an examination of initial vital signs is carried out before anesthesia is carried out such as the installation of blood pressure devices, ECG and pulse oximetry before induction, with pre-induction blood pressure with a blood pressure of 111/55 mmHg; pulse 50 x / min, and respiration 12 x / min; with saturation 100% room air. The patient was known to have hypertension with a history of treatment amlodipine 10 mg every 24 hours PO was taken at 00.00 WITA in the room, with a previous history that the patient did not routinely take medication.

The installation of a blanket warmer aimed to normalize patients during long surgeries. The state of hyperthermia was detrimental because high temperatures can cause cerebral metabolic rate, increase oxygen consumption and cause cerebral ischemia.⁴ Hypothermia causes a decrease in the cerebral metabolic rate where at a temperature of 33 – 34 oC causes a decrease in metabolic rate by 30 – 40%.⁵ In addition, it can reduce the decrease in cerebral blood flow by 1.1% for every decrease in cerebral metabolic rate by 5.1%.⁶ However, in long surgery, exposure to hypothermia can cause delirium.^{5,6} So that this patient was maintained to remain normothermia. Apart from that, for the environment, ensure that the patient's position is head up 15–30° and ensure that the neck is not bent, because this will inhibit return flow from the veins. In this patient, the arterial line of the radial artery manus sinistra was installed with lidocaine infiltration. The installation of arterial lines functions to monitor blood pressure accurately and continuously, in addition to being used to find blood samples so as to reduce the risk of infection due to repeated needle insertion.^{4,7} Installation of an arterial line functions to monitor blood pressure accurately and continuously, because changes in the patient's MAP affect CPP. MAP was maintained between 50 – 150 mmHg in the supine position, because if MAP < 50 mmHg it can cause cerebral ischemia, while MAP >150 mmHg can damage the constrictive power of blood vessels and cerebral blood flow, thereby causing damage to the blood brain barrier.⁴ CPP = MAP – ICP and average intracranial pressure measured at the

level of the foramen of Monroe, those that can increase ICP are large vein obstruction in the neck, Trendelenburg position, increased intra-abdominal pressure, resistance to chest expansion, PEEP >15, jugular vein cannulation. We used TCI or targeted controlled infusion to maintain the target plasma concentration of propofol, helping to maintain hemodynamic stability, and lowering the likelihood of respiratory depression.⁸

Remifentanyl is known to have little effect on cerebral blood flow and intracranial pressure, but may lower the cerebral metabolic rate of oxygen.⁹ Propofol is able to reduce cerebral blood flow, and reduce the cerebral metabolic rate by 19% so that it can provide neuroprotective effects in these patients.¹⁰ Dexmedetomidine is an α -2 adrenoceptor drug which has sedation and analgesic effects. Dexmedetomidine works in the central nervous system, causing hyperpolarization of noradrenergic receptors which results in an inhibitory feedback loop, thereby reducing norepinephrine release and stimulating sympatholytic effects.^{11,12} The use of sevoflurane is limited to neurovascular cases, because sevoflurane is able to prevent vasospasm. However, use of sevoflurane above 1 MAC results in an increased incidence of brain edema and increased ICP.^{8,13} PCO₂ is maintained between 35–45 mmHg.¹⁴

After intubation, there is increase in blood pressure with blood pressure even though before intubation has previously been given lidocaine spray.^{8,13} In patient, low flow anesthesia was performed, where the gas given was less than 1 l/minutes. The goal is to keep the humidity from the patient's respiratory tract from drying out, it's also save the need for anesthetic gas, more environmentally friendly, but LFA has a risk of forming a hypoxic mixture or inadequate anesthetic depth, so that this patient was given a high oxygen fraction of 90% and close monitoring. The concentration of oxygen contained in expiratory is always less than the gas inspired by the patient's consumption. In general, hypertension will occur during scalp incision induced by pain, in this patient a scalp block was performed before the incision is performed. The selection of analgesics with

remifentanyl is a short-acting opioid with a short duration. The drug binds to neurotransmitter receptors, constricts blood vessels in the brain and protects the autoregulatory function of the brain. Used in combination with propofol and sevoflurane aims to maintain intracranial pressure and increase cerebral perfusion pressure so that brain relaxation is achieved.¹⁵ In neurosurgical surgery, it is important to maintain brain oxygenation and perfusion. Patients are given intermittent rocuronium as a non-depolarizing type muscle paralyzing agent that does not cause cardiovascular changes or histamine release and vasodilation in patients, besides that it can also further relax patients during intubation.¹⁶

STA – MCA anastomosis involves the superficial blood vessels of the temporal artery to the branches of the middle cerebral artery to bypass vascular blockages in patients with MMD. This procedure aims to prevent recurrence of strokes and improve blood perfusion to the ischemic cerebral area.¹⁴ Direct anastomosis achieved by connecting the STA with the distal branch of the MCA. One of the branches of STA is used as a donor. Parturition of the donor vessels is done with a ultrasonography, by placing a probe on the distal part of the STA before anastomosis and blood flow is measured for 5 minutes. Furthermore, to assess occlusion in the vessels, assessing blood flow and bypass measured and recorded at 1, 2, 3, 4, 5, 15 and 30 minutes. In this patient, an extracranial – intracranial procedure can cause the depletion of cerebral oxygen reserves in the microcirculation that is maximally dilated, and the ratio of oxygen extraction will increase.¹⁷ Blood pressure maintain at range from 10 to 20% of basal blood pressure. Hypotension in these patients can stimulate hypoperfusion from the brain. In patients given appropriate fluid therapy to maintain normovolemia, in which ringer fundin is given as fluid therapy. Mannitol 0.5 mg/kgBW was given before opening the dura. The use of mannitol during surgery aims to achieve brain relaxation, causing retraction of brain tissue thereby reducing the occurrence of retractor induced ischemia.¹⁸ To achieve brain relaxation, this is by reducing intracranial volume, including brain tissue, blood and cerebrospinal

fluid.^{18,19} Mannitol is a hyperosmotic fluid that increases plasma volume rapidly, reduces blood viscosity, increases cerebral blood flow, causes cerebral vasoconstriction and reduces CSF production. The slow effect of administering mannitol is to change blood osmolarity, which causes fluid in the interstitial tissue to move into the blood vessels, causing dehydration of brain tissue, cerebral vasoconstriction which ultimately results in a decrease in ICP.^{18,19} In recent research, it is stated that a better choice than mannitol is hypertonic saline.¹⁹

During the procedure, fluid therapy was given with an appropriate crystalloid balance to ensure normovolemia, for this reason we gave ringerfundin as fluid therapy. Balance crystalloid has chloride which is closer to the chloride levels in the body by replacing the chloride substance with other anions such as lactate and acetate.²⁰ The choice of ringerfundin was due to its ability to maintain acid-base and electrolyte balance in patients.²⁰ After completing the STA-MCA augmentation, we administered nimodipine to prevent vasospasm in the connected blood vessels. Nimodipine is a dihydropyridine blocker drug which inhibits Voltage Dependent Calcium Channels - L Type. Next, nimodipine will bind to the alpha 1 subunit which contains transmembrane pores and voltage sensors which play a role in negative allosteric modulator channel function. L Type Calcium Channels are frequently activated in pathological arteries in the brain. L – Type calcium channels actively play a role in the CNS and play an important role in calcium accumulation, gene expression and excitability. So that administration of nimodipine can bind to the L Type Calcium Channels receptor and reduce excitatory mediators and reduce ischemia in cerebral blood vessels. During the surgery, patient was stable hemodynamic systolic blood pressure of 100 – 120 mmHg and diastolic blood pressure of 45–70 mmHg with bleeding of 600 ml, ringer fundin 3000 ml, urine of 800 mg with anesthesia duration of 9 hours and 15 minutes, and surgery duration of 7 hours and 15 minutes. A neuromuscular reversal agent was given with sugamadex, and a postoperative analgetic in the form of fentanyl 300 mcg was given to

keep the patient painless, normocapnia and avoid agitation when the patient was awakened. The use of sugamadex was chosen because it provides a more stable effect in waking the patient compared to reversal with neostigmine. Sugamadex is a γ -cyclodextrin class drug which binds strongly to the steroidal group NMBA, which can completely eliminate the effects of rocuronium. Postoperative analgesics were given with fentanyl 300 mcg in 0.9% NaCl 50 ml at a rate of 2.1 ml/hour and Paracetamol 1000 mg every 8 hours IV. The patient was extubated immediately after the operation was completed. This procedure has a risk of post-operative bleeding of 3–8%, post-operative ischemia of 3–8%, hyperperfusion syndrome of 4%. To avoid the risk of complications in patients, close post-operative ICU monitoring was carried out for 48 hours. Postoperatively, the patient was treated in the ICU for 24 hours after surgery.

Conclusion

In MMD, the aim of anesthesia management is to protect perfusion of brain tissue during the clamping period and tissue anastomosis. The clamping process can increase intracerebral pressure, therefore made sudden increase in mean arterial pressure to increase intracerebral perfusion. But in case of Moyamoya disease there are also collateral arteries that exist. Sudden and prolong increase in MAP can damage other brain tissue by stealing process. In this case, we conclude that the use of balance anesthesia with neuroanesthesia considerations, by maintaining airway patency during the operation, maintaining the oxygenation level, using drugs that can lower the cerebral metabolism balancing hemodynamics conditions, and preventing vasospasm. Correct management enhances the change to extubate and therefore good prognosis for this patient.

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