CASE REPORT

Anesthesia for ASD Closure in Robotic-Assisted Cardiac Surgery: A Case Report

Muhammad Rizqhan*, Yudi Hadinata*

*Harapan Kita National Cardiovascular Center, Jakarta, Indonesia
*Department of Cardiovascular Surgical Anesthesia, Harapan Kita National Cardiovascular Center, Jakarta, Indonesia

✉Correspondence: m.rizqhan@gmail.com

ABSTRACT

Background: Minimally invasive cardiac surgery (MICS) utilizes small chest incisions without sternotomy, offering faster recovery, reduced physiological stress, shorter hospitalization, and better cosmetic results. Robotic-assisted surgery is a modern approach within MICS that provides enhanced precision. However, literature on anesthesia management in robotic-assisted atrial septal defect (ASD) closure remains limited. This case report aims to provide clinical insights and support the safe adoption of such techniques.

Case: A 51-year-old male with an ASD secundum and a left-to-right (L-R) shunt measuring 22x29 mm, without comorbidities, was scheduled for general anesthesia. The patient was classified as American Society of Anesthesiologists (ASA) physical status III. Monitors applied included electrocardiogram (ECG), nasopharyngeal thermometer, arterial line, central venous pressure (CVP), $EtCO_2$, near-infrared spectroscopy (NIRS), and transesophageal echocardiography (TEE). The patient was placed in a supine position and intubated with a 37 Fr left-sided double-lumen endotracheal tube (DLT) at a depth of 31 cm, followed by one-lung ventilation. General anesthesia was induced using midazolam 5 mg, sufentanil 10 mcg, propofol 50 mg, and rocuronium 50 mg, maintained with 1% sevoflurane and rocuronium at 10 mg/hour. A regional block was performed using a deep serratus anterior plane block (DSAPB) with a regimen of 10 ml of 0.5% isobaric bupivacaine (50 mg), 5 ml of 10% lignocaine (500 mg), and epinephrine 1:200,000, with a total volume of 40 ml. The surgery was performed on a beating heart with right femoral artery, right femoral vein, and right jugular vein cannulation. The procedure lasted 12 hours.

Discussion: Robotic-assisted cardiac surgery enhances surgical accuracy but presents unique anesthetic challenges due to patient positioning, limited access, and cardiopulmonary dynamics. Anesthesiologists must optimize monitoring and maintain close team coordination.

Conclusion: Robot-assisted MICS represents a significant advancement in MICS. However, anesthesiologists must pay close attention to preoperative, intraoperative, and postoperative assessments to ensure patient safety and optimal outcomes.

Keywords: atrial septal defect; cardiac robotic surgery; deep serratus anterior plane block; minimal invasive robotic cardiac surgery; one lung ventilation

INTRODUCTION

Conventional cardiac surgery, performed with a sternotomy to access the mediastinum and coronary structures, has been extensively studied in the literature. Modern cardiac surgery continues to evolve alongside technological advancements in surgical practice, incorporating robotic assistance to facilitate cardiac procedures. Robotic-assisted surgery has been developed for coronary revascularization, valve disease treatment, atrial septal defect (ASD) repair, and atrial fibrillation management. Minimally invasive cardiac surgery (MICS) refers to procedures performed through small incisions, avoiding sternotomy and, in some cases, eliminating the need for cardiopulmonary bypass (CPB). Robotic-assisted cardiac surgery is one of the minimally invasive techniques that can be performed on both a non-beating heart and a beating heart.[1]

MICS is an attractive option for many patients, partly because it offers several advantages over conventional surgery, such as reduced postoperative pain, shorter hospital stays, faster recovery, and lower risks of wound infection, bleeding, and respiratory complications.[2] Complications associated with robotic-assisted cardiac surgery include cardiac arrest, atrial fibrillation, bleeding, kidney failure, and vascular complications.[3] Aortic manipulation during cannulation and cross-clamping increases the risk of aortic dissection, arterial embolization, and stroke.[4]

Anesthesiologists face several challenges in robotic-assisted cardiac surgery, including one-lung ventilation, carbon dioxide insufflation into the thoracic cavity, hemodynamic instability, the risk of carbon dioxide embolism, and limited access, which makes rapid interventions such as cardiopulmonary resuscitation more difficult.[5]

Postoperative pain is a significant issue in cardiac surgery, and opioids are often used for intraoperative and postoperative pain management. However, they carry risks such as side effects and dependence. Multimodal analgesia, which combines various medications and regional anesthesia techniques, is increasingly recommended to reduce opioid use and associated side effects.[6] The regional anesthesia technique using ultrasound guidance has become an essential component of multimodal analgesia. Deep serratus anterior plane block (DSAPB) is a nerve blockade technique for the chest wall, in which local anesthetic is injected into the plane of the serratus anterior muscle under ultrasound guidance.[7]

CASE

A 55-year-old male patient presented with complaints of shortness of breath during physical activity for the past nine months. The shortness of breath improved with rest and worsened with moderate activity (such as climbing two flights of stairs). The patient denied experiencing paroxysmal nocturnal dyspnea (PND) and dyspnea on exertion (DOE) and reported being able to sleep comfortably with one pillow. The patient was previously diagnosed with an enlarged heart through a chest X-ray in 2011 and experienced a cough at that time. However, he had no further complaints until March 2024. In July 2024, during a routine cardiac examination, an ASD was detected. The patient denied any history of past illnesses such as diabetes mellitus, hypertension, dyslipidemia, asthma, or pulmonary tuberculosis. He also reported no known allergies. During hospitalization, the patient was diagnosed with secundum ASD with a left-to-right (L-R) shunt and was scheduled for surgical ASD closure using a beating heart technique.

Preoperative physical examination revealed that the patient weighed 86 kg, had a height of 172 cm, and a body mass index (BMI) of 29.06 kg/m^2. The general condition of the patient appeared mildly ill, with full consciousness. Vital signs showed a blood pressure of 131/77 mmHg, heart rate of 80 bpm, respiratory rate of 18 breaths per minute, temperature of 36.5°C, and oxygen saturation of 99%.

Laboratory results showed hemoglobin (Hb) of 13.2 g/dL, hematocrit (Ht) of 38.2%, leukocytes at 8,790/µL, platelets at 348,000/µL, erythrocyte sedimentation rate (ESR) of 15 mm/hour, SGOT of 20 U/L, SGPT of 15 U/L, urea of 31 mg/dL, creatinine of 1.2 mg/dL, estimated glomerular filtration rate (eGFR) of 73 ml/min/1.73m^2, sodium of 142 mmol/L, potassium of 3.5 mmol/L, chloride of 110 mmol/L, calcium of 1.2 mmol/L, magnesium of 0.44 mmol/L, C-reactive protein (CRP) of 2 mg/L, and HBsAg non-reactive. Arterial blood gas (ABG) analysis revealed a pH of 7.4, pCO_2 of 36.4 mmHg, pO_2 of 87.3 mmHg, HCO_3 of 22.9 mmol/L, base excess (BE) of -2.1, SaO_2 of 97.3%, and lactate of 1 mmol/L.

Radiological examination using a chest X-ray showed a normal heart size with a cardiothoracic ratio (CTR) of 50% and thickening of the right hilum. Transesophageal echocardiography (TEE) revealed an ASD secundum measuring 22x29mm with an L-R shunt, normal left ventricular systolic function, a left ventricular ejection fraction (LVEF) of 81%, global normokinesis, and normal right ventricular contractility (Figure 1). Right heart catheterization (RHC) confirmed ASD secundum with high flow and low resistance, non-significant coronary artery disease (CAD), a flow ratio (FR) of 2.4, pulmonary vascular resistance (PVR) of 0.8 wood units (WU), indexed PVR (PVRi) of 1.5 WU/m^2, and a PVR/SVR ratio of 0.05. Before surgery, the patient was classified as ASA physical status III, with a planned general anesthesia, placement of invasive arterial line monitoring, central venous catheter insertion, and a 6-hour preoperative fasting period.

During the preoperative visit, the patient's hydration status was ensured to be adequate, and maintenance fluid requirements were adjusted using Ringer's Lactate. The patient was positioned in the supine position and intubated with a 27-size DLT at a depth of 29 centimeters, followed by one-lung ventilation. General anesthesia was induced using midazolam 5 mg, sufentanil 10 mcg, propofol 50 mg, and rocuronium 50 mg. DSAPB was performed after general anesthesia was induced. The patient received 0,5% isobaric bupivacaine 50 mg (10 cc) and lignocaine 500 mg (5 cc), diluted to a total volume of 40 cc, which was then injected into the space between the serratus anterior muscle and the ribs under ultrasound (USG) guidance. Anesthesia maintenance was achieved with sevoflurane 1% and rocuronium 10 mg/hour. Intraoperative monitoring included near-infrared spectroscopy (NIRS) to assess tissue oxygenation during surgery (Figure 1).

Cannulation for CPB was performed via the femoral artery, femoral vein, and internal jugular vein under TEE guidance. The operator made incisions at the second, fourth, and sixth intercostal spaces lateral to the right midclavicular line and at the fourth intercostal space anterior to the right anterior axillary line for robotic arm docking (Figure 2). Lung-protective strategies to minimize lung damage include maintaining FiO2 as low as possible, using low tidal volumes (6 mL/kg body weight) to keep peak airway pressure below 35 cmH2O, applying positive end-expiratory pressure (PEEP) of 5-8 cmH2O, and allowing permissive hypercapnia. Immediately after one lung ventilation (OLV) initiation, a gradual decrease in oxygenation and arterial saturation occurs, which is compensated by an increase in hypoxic pulmonary vasoconstriction (HPV).[8]

The surgery was performed under heart-beating conditions with a total duration of 12 hours. The CPB process lasted for 8 hours. During the procedure, the patient's hemodynamic parameters were maintained as follows: systolic blood pressure between 90-110 mmHg, diastolic blood pressure between 60-70 mmHg, heart rate of 75-90 bpm, respiratory rate of 12 breaths per minute, temperature between 34-37°C, and oxygen saturation of 96-99%. The patient's hemodynamic status is illustrated in Figure 3. After the surgery was completed, the patient was transferred to the intensive care unit.

The patient received intensive care for three days with relatively stable hemodynamics. Extubation was performed on the second day, and after ensuring the patient's stability, he was transferred to the intermediate ward.

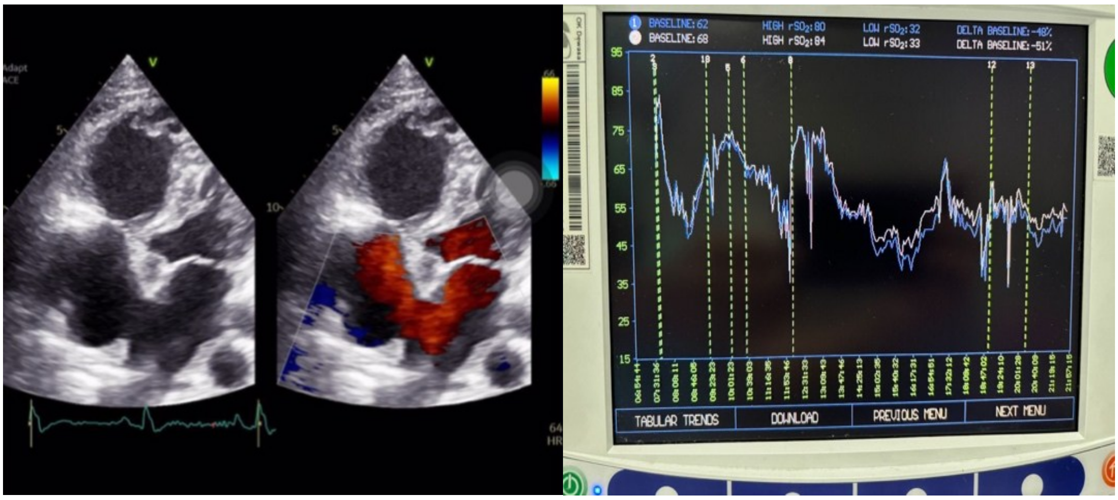


Figure 1. Echocardiographic image of the patient and NIRS monitoring

Figure 2. Illustration of incision sites, robotic arm placement, and patient position

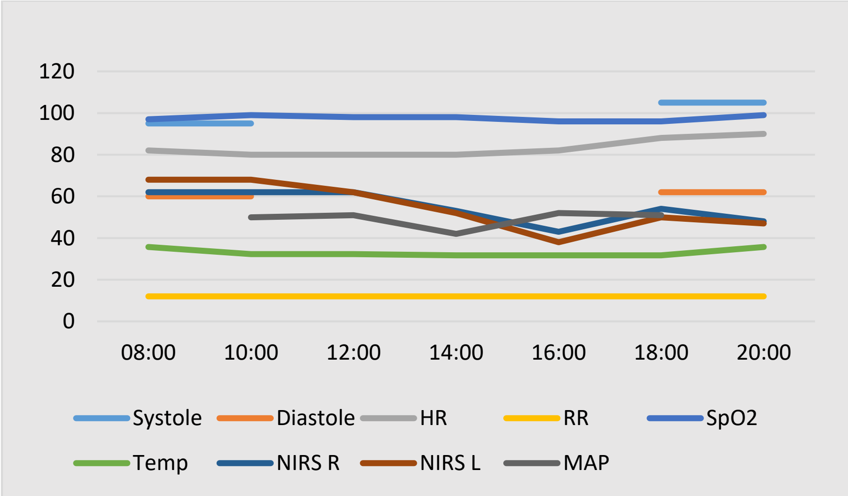
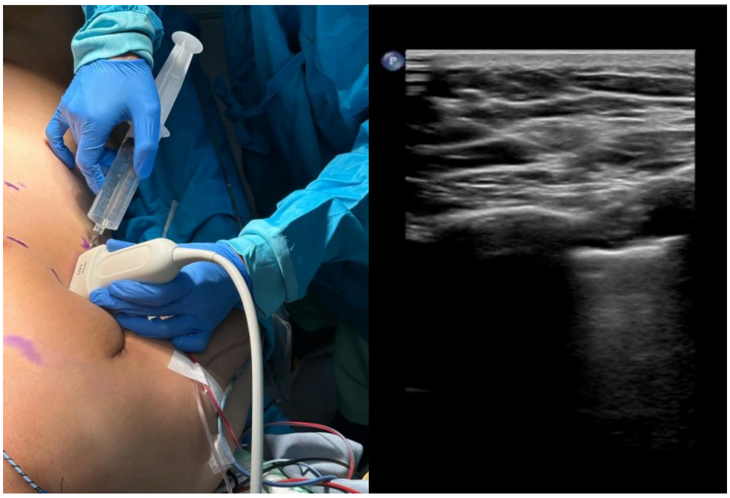


Figure 3. Hemodynamic overview during surgery



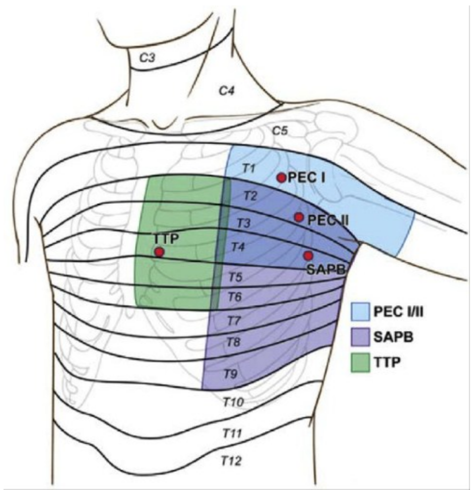


Figure 4. Illustration of deep SAPB and the analgesia coverage

DISCUSSION

This robotic-assisted cardiac surgery procedure is the first to be performed in Indonesia. It was used for ASD closure, and compared to traditional cardiac surgery with sternotomy, robotic-assisted surgery offers several advantages, including reduced postoperative pain, leading to lower analgesic use. Additionally, this method allows for faster recovery due to minimal incisions, resulting in improved patient quality of life. However, this technique generally has a longer operative time and higher costs compared to sternotomy. Potential side effects and complications must also be considered, such as injury to organs and blood vessels, burns, and even mortality. Other possible complications include subcutaneous emphysema, which occurs in approximately 45.7% of patients undergoing robotic cardiac surgery, as well as stroke, atrial fibrillation, reoperation due to bleeding, aortic reclamping, coronary lesions, the need for transfusion, and respiratory complications.[9]

ASD is an opening in the interatrial septum. There are three main types of ASD: sinus venosus, ostium primum, and ostium secundum. ASD can also occur in the coronary sinus, though this accounts for only 1% of all ASD cases. Complex ASDs are often associated with other anatomical abnormalities, such as Eisenmenger syndrome, and patients with congenital heart disease may remain asymptomatic until adulthood. Anesthetic management must consider major complications, including pulmonary hypertension, right heart failure, and the severity of the shunt.[10] Preoperative echocardiography is essential for evaluating the underlying pathophysiology of the disease, which may worsen significantly and unexpectedly.[11] The patient in our case was deemed suitable for robotic cardiac surgery because no pulmonary hypertension was detected on echocardiography or RHC.

General anesthesia is used in this surgery to control hemodynamics and respiration. Robotic ASD closure always requires OLV before CPB to facilitate a right mini-thoracotomy. OLV can be achieved using a DLT in patients with impaired left ventricular function. ASD closure can worsen heart failure, requiring careful consideration during preoperative cardiac function evaluation, as well as perioperative and postoperative inotropic management.[12]

Preoperative evaluation must consider the patient’s primary cardiac disease, as proper patient selection is crucial for achieving optimal outcomes. The patient’s body anthropometry must be adequate for robotic instrument placement, and their ability to tolerate OLV should be assessed before surgery. A study evaluating totally endoscopic robotic-assisted ASD repair demonstrated that robotic technology allows open-heart procedures to be performed safely and effectively with minimal invasiveness. The study included patients aged 18 to 80 years with secundum-type ASD and a flow ratio (FR) greater than 1.5, which corresponds to our patient, a 55-year-old with secundum ASD and an FR of 2.4. In addition, patients with a BMI below 30–32 kg/m² are generally preferred for robotic cardiac procedures, as higher BMI may reduce intrathoracic workspace and increase the risk of external robotic arm collision or restricted range of motion.[13–16] Our patient’s anthropometric characteristics were within these recommended parameters, allowing optimal port placement and safe instrument maneuverability.

Patients with cardiac conditions such as CAD, pulmonary diseases like chronic obstructive pulmonary disease (COPD), tuberculosis, bronchitis, asthma, or cyanotic conditions such as tetralogy of fallot (ToF) or severe pulmonary hypertension require special attention. The effects of CO_2 insufflation on the cardiovascular system can lead to decreased cardiac output, cardiac tamponade, increased central venous pressure (CVP), mean pulmonary artery pressure (mPAP), and pulmonary capillary wedge pressure (PCWP), thereby increasing the workload on the right heart.

OLV and the formation of capnothorax during CO_2 insufflation cause respiratory disturbances, leading to V/Q mismatch, increased shunt flow, a large A-a gradient difference, and decreased arterial oxygen pressure (PaO_2). The airway narrows due to the use of a DLT. Incompletely emptied alveoli exert pressure on adjacent alveoli and ducts, leading to overinflation and damage from high inspiratory pressures during OLV, ultimately resulting in alveolar edema. Patients with the above conditions are not recommended for this procedure, as capnothorax formation can worsen respiratory dysfunction and cause hemodynamic instability due to obstruction of systemic venous return. In our case, the patient was suitable for robotic cardiac surgery as there was no history of COPD, lung infection, kidney dysfunction, liver dysfunction, pulmonary hypertension, or previous neurological disease.

Hypoxemia during OLV can be managed through interventions such as increasing FiO_2 to 1.0, reassessing DLT positioning, ensuring stable hemodynamics and optimal cardiac output, performing recruitment maneuvers on the ventilated lung, adjusting PEEP on the ventilated lung, oxygen insufflation followed by continuous positive airway pressure (CPAP) application of 1-5 cmH_2O on the non-ventilated lung, intermittently reinflating the non-ventilated lung, mechanically restricting blood flow to the non-ventilated lung, and, in cases of sudden severe desaturation, promptly reverting to two-lung ventilation as quickly as possible.[8]

Challenges that arise in patients undergoing long and complex cardiac surgery include the potential for upper airway edema due to prolonged surgery, the need to maintain lung isolation, an increased risk of hypoxemia, and airway trauma. Patients requiring OLV have a higher risk of developing acute lung injury in the postoperative period, both due to the effects of OLV and the surgical procedure itself. Anesthesia management, particularly mechanical ventilation, can influence the degree of perioperative lung injury.

Proper patient positioning during surgery is crucial for successful robot-assisted cardiac procedures. The correct position allows unrestricted movement of the robotic arms and facilitates percutaneous CPB initiation during the procedure. An increase in $PaCO_2$ during OLV insufflation is a concern, as it can cause coronary vasoconstriction. Ventilation management during insufflation involves maintaining insufflation pressure below 8-10 mmHg to minimize effects on systemic and pulmonary circulation, ensuring adequate ventilation to keep $PaCO_2$ between 35-45 mmHg, increasing minute ventilation (MV) by 20-30% to compensate for CO_2 retention, adjusting PEEP to 5-8 cmH_2O to prevent alveolar collapse, and administering sufficient intravenous fluids or vasopressors if hypotension occurs. It is also important to prevent progressive hypothermia during robot-assisted cardiac surgery, which can result from prolonged procedure duration, the use of cold intravenous fluids, respiratory gases, and CO2 insufflation.[17] Progressive hypothermia can lead to coagulopathy, increasing the risk of blood loss, impairing cellular antioxidant defenses, and low CPB arterial perfusion temperature has been associated with a higher incidence of postoperative acute kidney injury.[18]

Cannulation in conventional cardiac surgery via sternotomy is performed on the ascending aorta, superior vena cava, and inferior vena cava. With the development of MICS, particularly total robotic cardiac surgery, peripheral CPB access is utilized through the internal jugular vein, femoral artery, and femoral vein.[19] The selection of the cannulation site is determined by the procedure being performed, the degree of atherosclerosis at the cannulation site, and the patient's body shape. Femoral artery cannulation is more practical and carries a lower risk. Venous cannulation is performed through the femoral vein, with the right femoral vein being preferred due to its more direct alignment with the inferior vena cava (IVC). Possible complications during cannula placement include IVC perforation and air trapping, which can lead to an airlock during CPB.[20] The coronary sinus catheter is placed by the anesthesiologist through the right internal jugular vein, and the use of heparin at a dose of 100 units/kg is recommended before coronary sinus manipulation to prevent thrombosis.[21] TEE is used during anesthesia and surgical cannulation to ensure proper positioning within the correct blood vessels. Additionally, TEE is utilized to monitor complications such as aortic dissection, pericardial tamponade, and liver laceration.[22]

Reexpansion pulmonary edema (RPE) is a serious complication resulting from mechanical injury and ischemia-reperfusion injury to the lungs after undergoing OLV. Prevention measures include intermittent ventilation of the right lung during surgery to oxygenate lung cells and prevent hypoxic vasoconstriction in the pulmonary microvasculature. After the surgery is completed, full bilateral ventilation is restored, and the reserve blood from the CPB machine is gradually reintroduced into the fully expanded lung to reduce hydrostatic pressure in the pulmonary microvasculature. Mannitol 150 mL can be administered as a free radical scavenger. Mild hypothermia is applied in cases involving multiple procedures due to prolonged aortic clamp time.[23] Postoperatively, before the patient was transferred to the ICU, intra-lumen suction was performed on the DLT, and no blood was found. The DLT was then replaced with an ETT No. 8 KK.

Postoperative care for patients undergoing minimally invasive ASD closure does not differ significantly from the sternotomy procedure. A drain is placed in the pericardial and right pleural space after CPB removal, and the patient is then transferred to the cardiac intensive care unit. Drain removal is typically performed 24 to 48 hours postoperatively.[12]

DSAPB is a regional anesthesia technique that blocks the thoracic wall nerves. This block effectively inhibits the lateral cutaneous branches of the intercostal nerves, providing analgesia to the anterolateral chest wall. DSAPB also helps reduce the secretion of postoperative pain mediators, suppresses the inflammatory response, and decreases the release of inflammatory cytokines. Additionally, this technique can reduce opioid consumption and opioid-related side effects.[24] This case is consistent with the literature, in which the use of sulfentanyl was limited to only 20 mcg during induction, with no additional opioids administered throughout the procedure. Research has found that DSAPB is more effective than Superficial SAPB because the analgesic duration of DSAPB is significantly longer, with a duration of approximately 6.69 ± 1.18 hours.[25] Epinephrine was used in this block, where literature states that the combination of bupivacaine and epinephrine has a duration of action of 6 to 8 hours,[26] whereas the combination of epinephrine and lidocaine only extended the duration of analgesia from 139 minutes to 185 minutes.[27] In this case, we performed a combination of DSAPB regional block and general anesthesia, resulting in minimal opioid use and excellent analgesic effects.

Sevoflurane was used as the anesthetic agent in this case. Inhalation anesthesia contributes to myocardial protection through its preconditioning effects on the myocardium. The mechanism involved includes reducing cytosolic and mitochondrial calcium overload. A meta-analysis has shown that sevoflurane has beneficial effects in reducing morbidity and mortality by providing cardioprotective effects in patients after cardiac surgery. Intravenous anesthetics such as propofol also have cardioprotective effects by significantly reducing myocardial infarct size, lowering troponin release, and decreasing mortality rates after cardiac surgery.[28]

Continuous administration of neuromuscular blockade during surgery can trigger residual postoperative paralysis. This condition is more common when using long-acting neuromuscular blockers such as pancuronium, but is less frequent with intermediate-acting neuromuscular blockers such as cisatracurium or rocuronium. The approach to neuromuscular blockade in cardiac surgery involves an initial high dose of an intermediate-acting neuromuscular blocker to maintain paralysis for most of the procedure. The need for neuromuscular blockade significantly decreases during CPB with hypothermia, making continuous infusion or repeated bolus administration potentially unnecessary. Studies have shown that discontinuing continuous neuromuscular blockade during hypothermic CPB does not increase anesthetic requirements, does not raise the incidence of patient movement, and does not reduce venous oxygen saturation.[29]

Postoperative complications in patients with ASD include a defect in ASD closure, leading to right heart failure, which is the most common cause of death within the first 72 hours after surgery. Postoperative management with mechanical ventilation focuses on protecting the right heart, using a tidal volume of 6-8 mL/kg, peak plateau pressure <27 cmH2O, Driving Pressure <18 cmH2O, and PEEP <7 cmH2O.[30] In our case, there were no major postoperative complications, indicating that the surgery was successful.

CONCLUSION

Robot-assisted MICS greatly aids thoracic surgeons in performing operations with high precision, reducing trauma to the patient's body, and accelerating the recovery process. However, it is also essential to consider the risks and potential complications of the procedure. The success of this technique depends on proper patient selection, and further research and trials are needed to determine the best approach for patients. This procedure takes a long time as it is still a relatively new learning process in the field of thoracic cardiovascular surgery in Indonesia, making each step and stage a valuable learning experience.

The assessment by an anesthesiologist is crucial in MICS techniques and the challenges they present. The anesthesiologist must enhance the preoperative evaluation, especially in patients with ASD, by assessing symptoms, cardiac function, and valve function through echocardiographic examination. Intraoperatively, they must monitor and maintain the patient's hemodynamics and manage potential complications during surgery. Additionally, postoperative assessment and intensive care management are essential.

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