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SÉRIE DE CASOS / CASE SERIES

Initial Anesthetic Experience in Robotic Cardiac Surgery: Case Series from a Tertiary Care Centre in India

Experiência Anestésica Inicial em Cirurgia Cardíaca Robótica: Série de Casos de um Centro de Cuidados Terciários na Índia

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Palavras-chave
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ABSTRACT
One of the most recent developments in surgical practice is minimally invasive robotic surgery. The use of surgical robots facilitates less invasive surgery. This approach to cardiac surgery offers numerous potential advantages to the patient, including reduced pain, shorter hospital stay and a quicker return to the day-to-day activity. Robotic surgery requires anesthesia personnel to incorporate various subspecialty skills to improve patient outcomes. In the era of minimally invasive surgery and the rising popularity of robotic cardiac surgeries, the cardiac anesthesiologist must be well versed with the various robotic systems and associated complications, have expertise in transesophageal echocardiography (TEE) and mastering and management of lung isolation techniques. Close coordination and planning with the surgical and perfusion team is essential for ensuring safe patient care. This is a case series that serves to explain some of the anesthetic challenges that were encountered during the commencement of robot-assisted cardiac surgeries.

RESUMO
Um dos desenvolvimentos mais recentes na prática cirúrgica é a cirurgia robótica minimamente invasiva. A utilização de um robô cirúrgico facilita uma cirurgia menos invasiva. Esta abordagem à cirurgia cardíaca oferece inúmeras vantagens potenciais ao doente, incluindo a redução da dor, um menor tempo de internamento hospitalar e um regresso mais rápido às atividades diárias. A cirurgia robótica exige que o pessoal de anestesia incorpore várias competências de subespecialidade para melhorar o resultado do paciente. Na era da cirurgia minimamente invasiva e da crescente popularidade das cirurgias cardíacas robóticas, é imperativo que o anestesiologista cardíaco esteja bem familiarizado com os vários sistemas robóticos e complicações associadas, experiência em ecocardiografia transesofágica (ETE) e domínio e gestão de técnicas de isolamento pulmonar. A coordenação e o planeamento próximos com a equipa cirúrgica e de perfusão são essenciais para garantir um atendimento seguro ao doente. Esta é uma série de casos que serve para explicar alguns dos desafios anestésicos encontrados durante o início das cirurgias cardíacas assistidas por robô.

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INTRODUCTION
Robotic-assisted cardiac surgery has revolutionized the field of cardiothoracic procedures, offering a minimally invasive alternative to conventional median sternotomy. In May 1998, the first robotic mitral valve (MV) repair was performed by Alain Carpentier in Paris, using an early prototype of the Da Vinci robotic device.[1] The use of robotics has expanded to pericardial procedures and placements of epicardial pacemaker leads as well.[2] While performed by trained personnel, it can ensure safety, excellent graft patency and reduced postoperative pain. Robotic surgery may have longer procedural time in comparison to open surgery.[3] Avoidance of median sternotomy and painful retractions leads to early recovery and quicker return to daily activities.[4] However, it necessitates specialized techniques such as one-lung ventilation (OLV) for optimal visualization of the heart and mediastinal structures, allowing for lung isolation and facilitating a clear operative field. OLV is associated with the risk of hypoxemia, hypercarbia and barotrauma. Intraoperative hypoxemia associated with OLV during robotic cardiac surgery is well documented.[5] The most important aspect of initiating OLV is correct placement of double lumen tube (DLT), using fibreoptic bronchoscopy as a misplaced tube defeat the goal of lung isolation.

This case series of nine cases aims to explore and highlight anesthetic challenges experienced during robot-assisted cardiac surgeries using OLV, which is an emerging field in developing countries like India.

CASE SERIES

A thorough preoperative assessment and diagnostic workup were carried out in all patients as listed in **Table 1**.

Anesthetic Management

Preoperative Anesthesia Assessment

The perioperative plan was formulated depending upon the patient's cardiac history, medical history, any pre-existing diseases, plan of surgery and need for one-lung ventilation. 2D Echocardiography, cardiac computed tomography (CT) and aortogram, carotid Doppler and pulmonary function test were conducted before formulating the plan of surgery. Smoking cessation was advised to all those with a history of smoking. Cardiac medications were continued as per protocol.

Operation Theatre Preparation

The robotic component of the da Vinci® Xi™ (**Fig. 1**) includes multiple robotic arms, which are quite large and can interfere with the anesthetist's working space, so proper positioning was done before handing over the patient. All defibrillator pads, endotracheal tubes, monitors, intravenous fluid lines, and invasive lines were placed and tapped properly before docking the robot, as after docking it becomes almost impossible to detect endotracheal tube dislodgement, disconnection of intravenous lines or starting of cardiopulmonary resuscitation (**Fig. 2**). Operation theatre (OT) was well-equipped to counter any complications. The functional anesthesia workstation was kept at an adequate distance to avoid interference with the robotic field. All essential monitors, including difficult airway cart, pacemaker, various sizes of endotracheal tubes, working laryngoscopes, extension for intravenous lines, body warming devices, and infusion pumps were kept at bay.[6] All patients were positioned supine with 30° elevation of the thorax on the operative site. Extension lines were used to keep intravenous lines patent and for easy accessibility. Pressure padding was done and body-warming devices were used.

Induction of Anesthesia

In all our patients, electrocardiography, arterial blood pressure, central venous pressure, oxygen saturation, core body temperature, capnography, arterial blood gas analysis (ABG), TEE, activated clotting time and urine output were continuously monitored throughout the perioperative period. Invasive arterial and venous lines were placed, and external defibrillator pads were applied to all. General anesthesia was

Table 1. Demographic data and preoperative findings of cases.

Case	Age (Yr)	Sex	Wt/Ht/BSA (Kg/cm/m²)	Diagnosis	Surgery	Co morbidities	Drugs	Cath/ Cardiac CT	Echocardiography	Carotid Doppler
1	48	F	53/160/ 1.53	Severe MS, Mild MR, NormalLV	MVR	Hypothyroid	Metoprolol, Dytor, Thyroxine	WNL	Severe MS, Mild MR, Normal LV	Normal
2	54	M	48/163/ 1.5	RHD Severe MR, Moderate MS	MVR	Temporo-parietal Glioma	Levetiracetam, Metoprolol, Dytor Ramipril	WNL	Severe MR, Moderate MS, Mean Gradient 13, EF 55%	Normal
3	46	F	45.3/159/1.43	RHD Severe MS, Moderate MR	MVR	Nil	Metoprolol, Diuretic	WNL	Severe MS Eccentric MR EF 65%	Normal
4	26	M	79/162/1.84	RHD Severe MS, Moderate MR, Mild TR, Moderate PAH	MVR	Nil	Metoprolol, Lasix Amiodarone, Warfarin	WNL	Severe MS, Eccentric MR EF 65%	Normal
5	39	F	39/148/1.27	RHD Severe Calcified MS	MVR	Solitary Kidney	Lasix, Dilzem, Acitrom	WNL	Severe MS Moderate MR Mild TR Moderate PAH	Normal
6	53	M	50.5/152/1.46	CAD (Single vessel disease)	OPCAB,LAD End	COPD, DM, Old TB	Ecospirin, Clopidogrel OHA, Metoprolol	90% occlusion of LAD	Concentric LVH, EF-60%	Normal
7	49	M	53/174/1.63	OS ASD	ASD Closure	Nil	Nil	OS ASD	OS ASD 4.2mm, RA And RV Dilated, EF 65%	Not Done
8	28	M	74/175/1.89	OS ASD	ASD Closure	Nil	Nil	OS ASD	OS ASD 40mm Normal Biventricular Function	Not Done
9	21	M	45/159/1.42	OS ASD	ASD Closure	Right bundle branch block	Nil	OS ASD	OS ASD Mild PAH	Not Done

Yr: years, Wt: weight, Ht: height, BSA: body surface area, MS: mitral stenosis, MR: mitral regurgitation, LV: left ventricle, RHD: rheumatic heart disease, TR: Tricuspid regurgitation, PAH: pulmonary artery hypertension, CAD: coronary artery disease, OS ASD: Ostium secundum atrial septal defect, MVR: mitral valve replacement, OPCAB: off-pump coronary artery bypass, LAD: Left anterior descending, WNL: within normal limits, EF: ejection fraction, LVH: left ventricle hypertrophy).

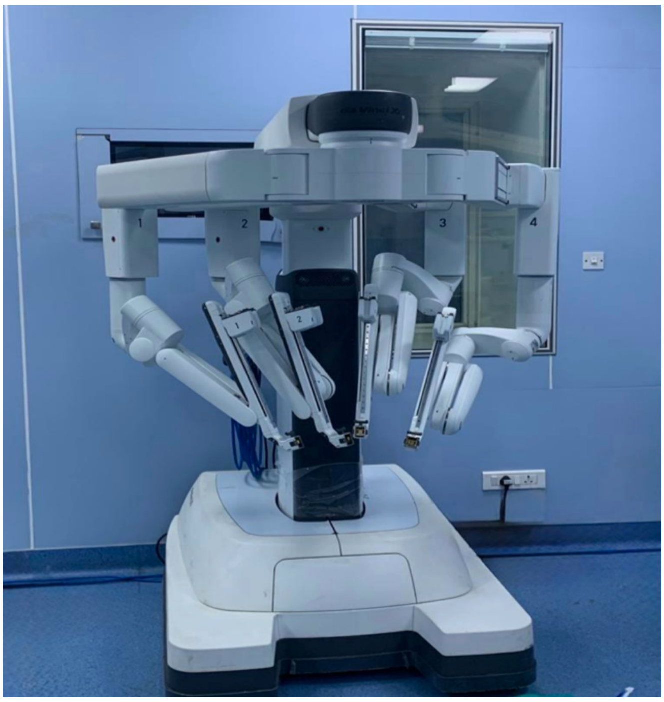

Figure 1. Robotic system da Vinci® Xi™

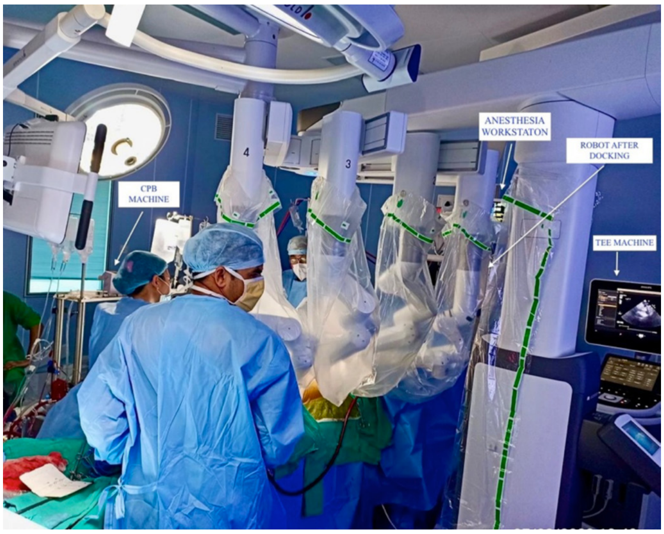

Figure 2. Intraoperative setup showing the position of anesthesia workstation, tee machine, cardiopulmonary bypass machine and the robotic system.

administered using intravenous induction agents, opioids, and muscle relaxants and the trachea was intubated using DLT of size 32 to 37F as per patient height and placement confirmed with fibreoptic bronchoscopy. Maintenance of anesthesia was done with fentanyl, vecuronium and inhaled anesthetic agents. Preoperative transthoracic echo findings were reconfirmed using TEE. A baseline ABG was done before inducing the patient, followed by periodic measurements after induction of anesthesia, during double lung ventilation, during one lung ventilation, during and after cardiopulmonary bypass (CPB) and after completion of surgery.

One Lung Ventilation and Capnothorax

The robot-assisted procedures required continuous OLV technique using DLT to give easy access to the surgeon into the chest cavity and the pericardium. Carbon dioxide was insufflated in hemithorax in robotic cardiac surgeries for adequate exposure of the heart and great vessels. The gas was insufflated with a pressure not exceeding 10 mmHg to avoid an excessive increase in intrathoracic pressure. Ventilating independently different parts of the lungs with different pressures may help force the air into atelectatic parts, reduce ventilation-perfusion mismatch and improve oxygenation.[7] The main challenge that we encountered while using OLV was hypoxemia, especially while coming off the pump. Some alveoli are overinflated and damaged secondary to high inspiratory pressure during OLV, resulting in alveolar edema.[8] Patients with ischemic heart disease who undergo coronary artery bypass graft are especially vulnerable during hypoxemia and prompt treatment is mandatory to ensure the patient's safety.[9]

Cardiopulmonary Bypass

Management of CPB for robotic surgery was similar to that of conventional cardiac surgery. The intraoperative data regarding the cannulation data and cardiopulmonary bypass data are summarised in **Table 2**. Arterial and venous cannula placements were done under TEE guidance, followed by monitoring of aortic root pressure and vacuum-assisted venous drainage. Cardioplegia was administered through a port in aortic cannula after which transthoracic aortic clamping was done. Weaning of CPB was done very carefully as de-airing of heart was difficult due to lack of direct access to the heart. Volume assessment and need for inotropic support were guided by TEE. Heparin was reversed using protamine after the procedure in all the patients. We routinely give tranexamic acid 10 mg/kg before going on pump and 10mg/kg after coming off pump in expected prolonged surgeries.

Post-Operative Course

All patients were shifted to the intensive care unit after changing over to single-lumen tube for elective mechanical ventilation. Adequate pain relief was ensured intraoperatively with multimodal analgesia technique using intravenous opioids (fentanyl) and NSAIDS and local infiltration with bupivacaine 0.25% at the port sites and postoperative analgesia was ensured with intravenous fentanyl and intravenous paracetamol. Once clinical and metabolic parameters were deemed fit they were extubated. The details of the postoperative course and complications have been summarised in **Table 3**.

DISCUSSION

Robotic cardiac surgical techniques with smaller incisions spare the patient from sternotomy and its consequences, allows enhanced recovery, early mobilisation and reduced duration of hospital stay. However the anaesthesiology team needs to develop and perfect techniques to manage these patients in the perioperative period which include TEE, guidance for peripheral cannulation and lung isolation techniques.

TEE provides crucial insights into baseline cardiac function,

Table 2. Intraoperative period.

Case	Position	Lines	SVC Cannula Size (French)	IVC Cannula Size (French)	DLT (Size, side, Fixed at cm)	Induction To OLV (Minutes)	CPB Time (Minutes)	Clamp Time (Minutes)	Blood (Yes/No)	Hemo-filteration (Yes/No)	Surgery Duration (Minutes)
1	Supine right up	Subclavian V, Fem art	16	20	35, L,27	75	284	163	Yes	Y	480
2	Supine right up	Subclavian V, Fem art	17	20	35, L,28	150	328	205	Yes	Y	620
3	Supine right up	Subclavian V, Fem art	16	20	35, L,27	75	568	395	Yes	Y	660
4	Supine right up	Subclavian V, Fem art	20	24	35, L,29	60	302	194	Yes	Y	480
5	Supine right up	Subclavian V, Fem art	14	18	32, L,26	90	225	154	Yes	Y	440
6	Supine Left Up	R IJV L Femoral	NA	NA	35, L,26	140	NA	NA	No	NA	590
7	Supine right up	Subclavian V, Fem art	17	20	37, L,29	100	131	75	No	NA	330
8	Supine right up	Subclavian V, Fem art	17	20	37, L,32	60	328	205	Yes	NA	540
9	Supine right up	Subclavian V, Fem art	18	14	37, L,28	35	121	60	No	NA	350

SVC: superior vena cava, IVC: inferior vena cava, DLT: double lumen tube, OLV: one lung ventilation, CPB: cardiopulmonary bypass, V: vein, fem art: femoral artery, R: right, L: left, IJV: internal jugular vein, NA: not applicable).

Table 3. Intraoperative complications and postoperative period.

Case	Hypoxemia (Yes/No)	Pacing (Yes/No)	DC Shock (Yes/No)	Bleeding (Yes/No)	Mechanical Ventilation Time (Hours)	ICU Duration	ReExploration (Yes/No)	Blood Transfusion (Yes/No)	Postoperative Issues
1	Yes	No	No	No	11	30 Days	No	Yes	Psychosis, Hemoptysis, Altered Mental Status
2	No	No	No	Y	36	96 Hours	Yes	Yes	Nil
3	No	No	No	Y	32	7 Days	Yes	Yes	Left Sciatic Neuropathy
4	No	No	No	No	14	60 Hours	No	Yes	Atrial Fibrillation
5	No	No	Y	No	16	50 Hours	No	Yes	Nil
6	No	No	No	No	9	63 Hours	No	No	Nil
7	Yes	No	No	No	18	44 Hours	No	Yes	Nil
8	Yes	No	No	Y	11	65 Hours	No	Yes	Headache, VPCs
9	No	No	No	No	3.3	25 Hours	No	No	Nil

DC: direct current, ICU: Intensive Care Unit, VPCs: ventricular premature complexes.

valvular lesions and can identify potential contraindications, such as dilated ascending aorta or severe aortic regurgitation. In robotic heart surgery, TEE is essential for precise positioning of guide wires and cannulae during peripheral CPB.[10] For example, while inserting the SVC cannula and femoral venous cannula guidewire should be visualized in the right atrium before attempting dilation and cannulation and while the femoral arterial guidewire must be confirmed in the descending aorta before cannulation.

TEE is also an essential guide for the de-airing of cardiac chambers as the heart is not fully accessible for manual ballottement technique for de-airing and for internal defibrillation in case of air induced arrhythmias

OLV plays a crucial role in robotic cardiac surgery by providing a safer area for surgeon to conduct the procedure without much risk of damaging nearby structures though it is associated with potential complications like hypoxia, hypercarbia, barotrauma and acid-base disturbances.

During OLV patients may experience hypoxemia and hypoxic pulmonary vasoconstriction subsequently. This may have occurred secondary to the obligatory right to left transpulmonary shunt through the non-ventilated, nondependent lung.[11] The hypoxemia was more during weaning off the bypass in 3 out of 9 of our patients experienced hypoxemia intraoperatively, which was corrected in subsequent gas analyses via providing 100% oxygen to the patients. During this time, intermittent positive pressure ventilation to both lungs was also required. Liu TJ *et al* conducted a study in patients experiencing hypoxemia during one-lung ventilation for robot-assisted coronary artery bypass graft surgery. They reported the incidence of hypoxemia in their patients (4.3%), which was remarkably lower than that reported in other studies. Another challenge with OLV is that DLT has to be replaced post-surgery, which may be difficult in cases of difficult airway or swelling of the pharynx post bypass.[12]

CO_2 insufflation during the procedure has been reported to cause gas embolism in other types of robotic surgery.[13] However none of our patients had experienced any complication secondary to CO_2 insufflation. Higher CO_2 insufflation pressures have been seen associated with a decline in cardiac index and hemodynamic consequences. Hemodynamics can be improved with judicious use of fluid and inotropes.

None of the patients who underwent robotic cardiac surgery required pacing. DC shock was administered to only one patient undergoing mitral valve replacement surgery. The majority of our patients required blood transfusion as it is very common in cardiac surgeries due to the nature of the surgery, low preoperative hematocrit in our patient subset, length of CPB, use of antiplatelet agents etc. Although operative time was longer compared to conventional technique due to the initial learning curve of the surgeons, postoperative complications such as left sciatic neuropathy, headache, premature beats, psychosis, altered sensorium and hemoptysis were low and the majority of the patients had uneventful stays in the Intensive care unit. Perioperative analgesia was ensured to all the patients to help in smooth emergence and successful extubation.

CONCLUSION

In the era of minimally invasive surgery and rising popularity of robotic cardiac surgeries it is imperative for the cardiac anesthesiologist to be well versed with the various robotic systems and associated complications, expertise in transesophageal echocardiography and mastering and management of lung isolation techniques. Close coordination and planning with the surgical and perfusion team is essential for ensuring safe patient care.

DECLARAÇÃO DE CONTRIBUIÇÃO / *CONTRIBUTORSHIP STATEMENT*

IBM: Concept. design, literature search, data acquisition, data analysis, manuscript preparation and editing.
UB: Concept, design, literature search, manuscript preparation and editing.
PG and SK: Literature search, data analysis, manuscript preparation and editing.
All authors approved the final version to be published.

IBM: Conceito, conceção, pesquisa bibliográfica, aquisição de dados, análise de dados, preparação e edição do manuscrito.
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REFERENCES

1. Carpentier A, Loulmet D, Aupècle B, Kieffer JP, Tournay D, Guibourt P, et al. Chirurgie à coeur ouvert assistée par ordinateur. Premier cas opéré avec succès. C R Acad Sci III. 1998;321:437-42. doi: 10.1016/s0764-4469(98)80309-0.42.
2. DeRose JJ, Ashton RC, Belsley S, Swistel DG, Vloka M, Ehlert F, et al. Robotically assisted left ventricular epicardial lead implantation for biventricular pacing. J Am Coll Cardiol. 2003;41:1414-9.
3. Mohamed A, Shehada SE, Brakel LV, Ruhparwar A, Hochreiter M, Berger MM, et al. Anesthetic management during robotic-assisted minimal invasive thymectomy using Da Vinci system. A single center experience. J Clin Med. 2022;11:4274. doi: 10.3390/jcm11154274.
4. Bonaros N, Schachner T, Wiedemann D, Oehlinger A, Ruetzler E, Feuchtner G, et al. Quality of life improvements after robotically assisted coronary artery bypass grafting. Cardiology. 2009;114:59-66. doi: 10.1159/000212115.
5. Rehfeldt KH, Mauermann WJ, Burkhart HM, Suri RM. Robot-assisted mitral valve repair. J Cardiothorac Vasc Anesth. 2011;25:721-30. doi: 10.1053/j.jvca.2011.03.186.
6. Hafiani H, Choubhi M, Ameur A, Bensghir M, Abouelalaa K. Anesthetic considerations in robotic surgery: a comprehensive review. J Robot Surg. 2024;18:220. doi: 10.1007/s11701-024-01974-y.
7. Klingstedt C, Baehrendtz S, Bindslev L, Hedenstierna G. Lung and chest wall mechanics during differential ventilation and with selective PEEP. Acta Anaesthesiol Scand. 1985;29:716-21.
8. Chauhan S, Sukesan S. Anesthesia for robotic cardiac surgery. An amalgam of technology and skill. Ann Card Anaesth. 2010;13:169-175.
9. Liu TJ, Shih MS, Lee WL, Wang KY, Liu CN, Hung CJ, et al. Hypoxemia during one- lung ventilation for robot-assisted coronary artery bypass graft surgery. Ann Thorac Surg. 2013;96:127-32. doi: 10.1016/j.athoracsur.2013.04.017.
10. Deshpande SP, Lehr E, Odonkor P, Bonatti JO, Kalangie M, Zimrin DA, et al. Anesthetic management of robotically assisted totally endoscopic coronary artery bypass surgery (TECAB). J Cardiothorac Vasc Anesth 2013;27:586-99. doi: 10.1053/j.jvca.2013.01.005.
11. Baraka A. Differential lung ventilation as an alternative to one-lung ventilation during thoracotomy. Report of three cases. Anaesthesia. 1994;49:881-2.
12. Kiaii B, Bainbridge D, Fernandes P. Surgical, anesthetic, perfusion-related advances in minimal access surgery. Semin Cardiothorac Vasc Anesth 2007;11:282-7.
13. Hong JY, Kim JY, Choi YD, Rha KH, Yoon SJ, Kil HK. Incidence of venous gas embolism during Robotic-Assisted Laparoscopic radical prostatectomy is lower than that during radical retropubic prostatectomy. Br J Anaesth. 2010;105:777-781.