Robotic totally endoscopic mitral valve surgery with moderate hypothermic ventricular fibrillatory arrest

Miroslav P. Peev, Hiroto Kitahara, Kaitlin Grady, Husam H. Balkhy

Section of Cardiac Surgery, Department of Surgery, University of Chicago, Chicago, IL, USA

Correspondence to: Miroslav P. Peev, MD. Section of Cardiac Surgery, Department of Surgery, The University of Chicago Medical Center, 5841 S. Maryland Ave., Chicago, IL 60637, USA. Email: miro.peev@gmail.com.

Abstract: Moderate hypothermic ventricular fibrillatory arrest allows the conduct of a heart operation while avoiding aortic cross-clamping and at the same time enables continuous perfusion of the heart in a relatively still operating field. This technique has been originally described and used in cardiac surgery as an alternative to cardioplegic arrest and found particular application in patients with a history of prior cardiac surgery. For this particular group of patients, the main intention was to minimize the need for extensive and prolonged adhesiolysis. Recently, several studies have verified the safety and feasibility of hypothermic ventricular fibrillatory arrest for patients undergoing index cardiac surgery, which has led to increased adoption of this novel approach. Since the technique is also considered beneficial in minimally invasive cardiac surgery, several centers across the United States adopted this technique for patients undergoing mitral valve surgery through mini-thoracotomy approach. Our institution has further extended the use fibrillatory arrest in minimally invasive—total endoscopic mitral valve surgery. In this article, we describe in details our operative technique, critical steps including pearls, pitfalls and intraoperative challenges when using ventricular fibrillatory arrest in robotic mitral valve surgery. We highlight our selection criteria, operative and anesthesia setup as well as we report our sequence of events needed for the successful conduct of the operation. In addition, we deliver a summary of our postoperative results.

Keywords: Ventricular fibrillatory arrest; robotic mitral valve surgery; mitral regurgitation

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Introduction

Moderate hypothermic ventricular fibrillatory arrest technique has been used as an alternative to cardioplegic arrest in minimally invasive cardiac surgery (1,2). This alternative technique avoiding manipulation of the ascending aorta could be beneficial for patients with aortic calcification or significant atherosclerosis. The benefit of the technique has been mainly reported in patients with previous cardiac surgery since it minimizes the need for adhesiolysis (3,4). Additionally, these studies reported that the technique significantly decreased internal mammary artery graft injury and mortality. Based on the safety and simplicity of ventricular fibrillatory arrest technique, it has been used for not only cardiac reoperation but also primary intra-cardiac procedures through mini-thoracotomy approach (5,6). Since 2014, we have applied this technique for selected patients undergoing robotic totally endoscopic mitral valve surgery. In this article, we describe details of the operative technique of robotic mitral valve surgery with moderate hypothermic ventricular fibrillatory arrest.

All procedures performed in this study were in accordance with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this study and any accompanying video. A copy of the written consent is available for review by the editorial office of this journal.

Surgical technique

Indications, contraindications and patient selection

In our center, the preferred technique for robotic mitral valve surgery (in addition to most other intracardiac procedures) is cardioplegic arrest using endo-aortic balloon occlusion (IntraClude System, Edwards Lifesciences, Irvine, CA, USA). Moderate hypothermic ventricular fibrillatory arrest is selectively used for patients undergoing non-complex mitral valve repair or replacement. Although there is no strict indication for this technique, patients with a history of cardiac surgery, especially with patent internal mammary graft, severely calcified aorta, atherosclerosis in the aorta and peripheral vascular disease are preferable candidates. Relative exclusion criteria of the technique are aortic regurgitation more than mild, significant coronary artery disease and myocardial dysfunction.

Preoperative work-up

We conduct a standard preoperative work up that comprehensive blood panel as well as contrast enhanced computerized tomography to evaluate the anatomy of the vascular system. Pulmonary function tests are obtained in selected patients with strong smoking history or preexistent diagnosis of chronic obstructive pulmonary disease (COPD). Transthoracic echocardiogram is obtained to assess for any valvular diseases and heart function.

Anesthesia, patient positioning and port placement

Patient is placed supine with a roll under the right chest. External defibrillator pads are placed on the chest and back. General anesthesia is induced with a single lumen endo-tracheal tube. The right femoral artery and vein are exposed above the inguinal ligament through a small (3 cm) transverse groin incision, and purse-string sutures (4-0 mono-filament) are applied for cannulation. With the lungs deflated, an 8-mm working port incision is made in the 4th intercostal space in the mid axillary line, and then dilated with an 8-mm dilator and a soft tissue retractor is placed. Next, an 8-mm camera port is placed in the 4th intercostal space between the mid-clavicular and the anterior axillary line. Humidified carbon dioxide is continuously insufflated through this port in the pleural space, and the 8-mm working port is closed off with wet gauze to maintain intrathoracic pressure to allow resumption of ventilation without lung injury. It is noted that while the robotic ports are in the Valsalva maneuver should not be encouraged to reduce the risk of lung injury by the ports. Two 8-mm robotic ports are placed in the 2nd and 6th intercostal space in the anterior axillary and mid axillary lines for the left and right robotic arms respectively. An 8-mm robotic port for atrial retractor is placed in the anterior 5th intercostal space around the mid clavicular line.

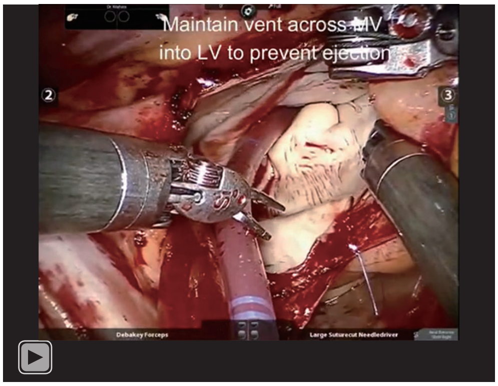
Cannulation and initial dissection

Cardiopulmonary bypass (CPB) is established with femoral arterial and venous cannulation. A percutaneous right internal jugular venous cannula into the superior vena cava for bicaval drainage is added for patients with large body surface area. For patients with a relatively small femoral artery or severe atherosclerosis of the aorta, the right axillary artery is alternatively used for arterial cannulation. In a case of redo-cardiac surgery, a right endobronchial blocker is placed to deflate the right lung selectively. In these cases, an initial 5-mm port is placed in the 4th intercostal space between the mid-clavicular and the anterior axillary line, and a thoracoscope is inserted to check for any adhesions between the lung and chest wall. If right lung adhesiolysis is required it can be performed thoracoscopically or robotically which is our preference especially for significant adhesions. Adhesions to the heart (right atrium) are better dissected after institution of CPB. The rest of the procedure in redo cases are same as will be described below.

A summarized video of the procedure has been attached to the manuscript (*Video 1*).

Moderate hypothermic ventricular fibrillatory arrest

After initiating CPB, the da Vinci surgical robot (Intuitive Surgical Inc., Sunnyvale, CA, USA) patient cart is docked from the left side of the table and the robotic arms are docked. Systemic cooling is started to down to 31 ℃ immediately upon initiating CPB. Two sump suction tubes are inserted percutaneously in the 5th and 6th intercostal spaces posterior to the working port. If necessary, the hemidiaphragm is retracted inferiorly by placing a suture (3-0 mono-filament) in the tendinous dome and bringing it out to the skin. The pericardium is opened longitudinally 2 cm above the phrenic nerve and pericardial retraction sutures (2-0 polyfilament) are placed taking care not to stretch the phrenic nerve. The oblique sinus is opened. An epicardial bipolar temporary pacing wire is placed in



Video 1 The following video describes our technique of mitral valve repair on a fibrillating heart. We demonstrate our standard setup as well as port placement followed by several steps in preparation for a fibrillatory arrest. The video displays the access to the left atrium followed by neochords creation and ring placement as a reproducible and safe technique.

the right ventricle either anteriorly or preferably on the diaphragmatic surface. A 14-G angiocath is inserted next to the retractor port in the 5th intercostal space, followed by insertion of a suture retriever for bringing the pacing wire out. The pacing wire is connected to a temporary external pacemaker (atrial side). Rapid ventricular pacing at a rate of 800 beats/min and amplitude of 20 mm amperes is applied for several seconds to induce ventricular fibrillation. It is key to have cooled the body core temperature down to 31 ℃ in order to easily induce ventricular fibrillation at this time. Alternatively, a transvenous right ventricular pacing wire through the internal jugular vein can be used and is beneficial to minimize pericardial dissection in redo cases. The external pacemaker should be kept on standby during ventricular fibrillatory arrest for accidental conversion to sinus rhythm which should be rare if the patient is hypothermic. Mean systemic arterial pressure is maintained at 80 mmHg during ventricular fibrillatory arrest for myocardial perfusion and preventing air from entering the ascending aorta.

Mitral valve procedure

After confirming stable ventricular fibrillatory arrest, a standard left atriotomy is made through the inter-atrial groove. A vent across the mitral valve should be immediately placed to decompress the left ventricle (LV). The left atrial wall should only be gently retracted upwards by the dynamic atrial retractor to prevent aortic regurgitation causing blood in the field and insufficient myocardial perfusion. Intraoperative assessment of the competency of the mitral valve can be done by allowing the LV to fill as well as by gentle saline injection with the robotic suction/irrigator. The mitral valve repair is then conducted in usual fashion. First, both or either of leaflet resection or artificial chordal implantation is performed based on the disease. We use 4-0 PTFE sutures in case if neochords are necessary for the repair. Then, an optimal size of a semi-rigid partial annuloplasty ring (Simulus® Annuloplasty Ring, Medtronic Inc., Minneapolis, MN, USA) is chosen under pressurized left ventricle and is secured by a 3-0 prolene continuous running mattress suture. The left ventricle is allowed to fill in order to check the final result of the repaired valve and adjust the height of the neochords after which they are tied. Re-warming is initiated. The vent is then turned off and positioned deep in the LV towards the apex to maximize de airing and activated only after filling the heart when left atrial closure is complete. The left atriotomy incision is closed using a single layer of 4-0 prolene running suture while the patient is slowly re-warmed. The second vent is placed in the left atrium to maintain visualization during left atriotomy closure but always taking care not to empty the left atrium completely otherwise air will be entrained into the left heart.

De-airing and defibrillation

Once the left atriotomy is closed around the LV vent, the second drain is removed from the left atrium and extensive de-airing maneuvers are then performed with filling of the heart and manipulation of the LV anterior wall and apex with a robotic instrument while applying high suction to the LV vent. The robotic instruments and camera are then removed, and the arms undocked briefly while direct cardioversion is applied using the external defibrillator pads. The robot is re-docked. The heart rate is maintained at around 80 (by ventricular pacing if necessary) while further de-airing is completed with filling the heart and placing the LV vent on high suction. Air in the left ventricle and the ascending aorta can be assessed by transesophageal echocardiography at this time. Finally, once adequate deairing has been performed the pericardial stay sutures are removed and gentle valsalva maneuvers are applied to the lungs while removing the LV vent.

Weaning off CPB and final steps

An epicardial temporary pacing wire is sutured in the right atrium where necessary. A 24 Fr chest tube is brought in from the retractor port and the tip placed in the pericardial space followed by closing the pericardium loosely with a running V-Loc™ suture (Covidien, New Haven, CT, USA). After confirming hemostasis in the suture line and in the port sites, the robot is un-docked and all ports are removed. Mechanical ventilation is resumed and CPB is weaned off after the body core temperature reaches 36 ℃.

Intraoperative challenges

Conducting robotic mitral valve surgery on a fibrillating heart is with no doubt a challenging endeavor on its own. There are few key potential obstacles that could be encountered during the surgery. First, considering the heart is not arrested, one should keep in mind that there will be some blood entering the operative field and affecting the visualization. We use a separate LV vent across the valve to mitigate this challenge. Second, to safely conduct the operation, we induce system hypothermia to 31 ℃. It is imperative to properly account for the time to cool and rewarm the patient without unnecessarily prolonging the CPB time. During the ventricular fibrillatory arrest we maintain mean systemic arterial pressure at 80 mm Hg to provide adequate myocardial perfusion and prevent any air from entering the ascending aorta. After concluding the mitral portion of the operation, we perform a variety of extensive deairing maneuvers as described in detail in the body of the manuscript.

Since 2014, we have used a ventricular fibrillatory arrest technique for selected patients who underwent robotic cardiac surgery. Of 546 patients who underwent robotic intra-cardiac procedures, 81 patients had mitral valve surgery with moderate hypothermic ventricular fibrillatory arrest. Around 15% of the patients had a history of previous cardiac surgery. The postoperative outcomes were equivalent to those in patients undergoing surgery with endo-aortic balloon occlusion. No significant residual mitral regurgitation was observed by transesophageal echocardiography after repair. There were no conversions to sternotomy and no postoperative myocardial infarction or cerebrovascular accident. These patients were discharged with the mean hospital length of stay of 3.2 days.

In order to achieve successful outcomes, we have created a high-volume practice that is served by highly experienced and dedicated robotic cardiac surgery team. In our previous work, we have highlighted the paramount importance of such minimally invasive team as the most effective way to overcome the steep learning curve associated with use of robotic technology for cardiac surgery.

Conclusions

Moderate hypothermic ventricular fibrillatory arrest technique has been safely performed for patients undergoing robotic totally endoscopic mitral valve surgery in our center. This procedure could be a safe alternative to the cardioplegic arrest technique for selected patients.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee(s) and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this manuscript and the accompanying video. A copy of the written consent is

available for review by the editorial office of this journal.

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