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Robotic-assisted cardiac surgery without aortic cross-clamping: A safe alternative approach

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Abstract

Background and Aim: Attempting to place an aortic cross-clamp may complicate surgery and postoperative outcomes in patients who have mediastinal adhesions or in those with extensive aortic calcification. Although right-sided cardiac surgery via thoracotomy is not a new technique in these patients, robotic-assisted intracardiac repair without cross-clamping was not reported in a large group of patients previously. In this study, the safety of robotic-assisted cardiac surgery without aortic cross-clamping was examined.

Methods: From January 2010 to March 2020, 304 patients underwent robotic-assisted cardiac surgery in our center and in 25 of these patients (8.2%) with a mean age of 65.5 ± 20 years myocardial protection was succeeded with moderate hypothermic ventricular fibrillatory arrest. Severe pericardial adhesions or existence of highly calcified ascending aorta were the indications for fibrillatory arrest during robotic assistant surgery.

Results: Most patients were in New York Heart Association Class ≥II (88.0%) and the mean logistic Euroscore value was 18.5 ± 22.3. The type of operations were mitral/tricuspid valve repair/replacement, cryoablation, atrial septal defect closure, and pericardiectomy. Cardiopulmonary bypass times were 141.5 ± 47 (minimum 77–maximum 252) min. There was no case of conversion to open thoracotomy or sternotomy. Hemiparesis was observed in one patient. Two patients with 78.2 and 81.9 Euroscore values had mesenteric ischemia and multiorgan failure, respectively, and died at postoperative period.

Conclusions: Robotic-assisted cardiac surgery without cross-clamping may provide reasonable outcomes in patients with severe aortic calcification or mediastinal adhesions undergoing intracardiac repair. These acceptable outcomes may encourage surgeons to perform this approach in appropriate group of patients.

KEYWORDS

aorta and great vessels, cardiovascular pathology, valve repair/replacement

1 | INTRODUCTION

In robotic-assisted surgery involving intracardiac repair, the most common strategy of myocardial protection is to perform the operation by placing an aortic cross-clamp and delivering cardioplegia, as it is performed in conventional operations. However, in patients who have previously undergone cardiac surgery with mediastinal adhesions, or in those with extensive aortic calcification, placing an aortic cross-clamp may complicate surgery and perioperative outcomes.[1] In this study, the safety of robotic-assisted cardiac surgery without aortic cross-clamping is examined in a specific group of patients.

2 | MATERIALS AND METHODS

From January 2010 to March 2020, 304 patients underwent robotic-assisted cardiac surgery in our center using Da Vinci Systems (Intuitive Surgical, Inc.) and in 25 of these patients (8.2%), the operation was completed without cross-clamping. The study was approved by the Institutional Review Board. Myocardial protection was succeeded with moderate hypothermia and ventricular fibrillatory arrest, except for patients requiring isolated right-sided surgery. The indications for operation without cross-clamping during robotic-assisted surgery were pericardial adhesions related to second or third cardiac surgery (redo) or existence of highly calcified ascending aorta. As well as previous operations via a sternotomy including coronary artery bypass grafting (CABG), mitral valve repair or replacement, tricuspid valve repair, or atrial septal defect (ASD) repair. In case of suspicion of ascending aorta calcification at echocardiography/chest X-ray or existence of peripheral arterial pulselessness chest/abdomen/pelvis was scanned with computed tomography regarding peripheral cannulation. Moreover, in patients with severe aortic calcification, arterial cannulation was performed with right axillary artery to avoid calcification related complications.

Data for this report, including medical histories, demographic characteristics, comorbidities, operative and laboratory results, ECG analysis, early postoperative outcomes were all retrieved retrospectively from the institutional database. Both techniques, robot-assisted surgery and conventional approach via sternotomy, were described in detail to all patients before operation and informed consent was taken. None of the patients had severe coronary artery disease requiring revascularization in this group. Our technique for robotic-assisted surgery was described elsewhere previously.[2] But briefly, after double-lumen tube intubation, transesophageal echocardiography (TEE) probe was inserted and intracardiac pathological findings were evaluated. A percutaneous venous cannula was inserted for venous drainage via right internal jugular vein and other venous cannula placed from femoral vein with TEE guidance. The suitable site for arterial cannulation was decided with Doppler USG and in case of severe atherosclerosis at femoral arteries, right axillary artery was another option. A chest roll was placed under the right shoulder, the right arm was placed at the side of the operation table. A soft tissue retractor was placed following a 3 cm incision between the anterior axillary and midclavicular line at the fourth intercostal space. The port for the robotic right arm was placed through the first or second intercostal spaces inferior to the soft tissue retractor, and the left arm port was placed one intercostal space superiorly.

After the positioning of the trocars, the robotic system was docked. Following cardiopulmonary bypass (CPB) institution, the pericardium was opened 2–3 cm anteriorly to the phrenic nerve, pulled through the lateral chest wall inferior to the thoracotomy, and fixed externally. Moderate hypothermia, around 31–32°C, was applied during CPB. The inferior and superior venae cavae were occluded with bulldog clamps. The heart was fibrillated via fibrillator cable which was delivered through the service port. Following left or right atriotomy, an extra vent was placed in atrium to collect extra blood and then the exposure was established by robotic retractor.

Continuous carbon dioxide was insufflated (5 L/min) to de-air and vacuum assist via venous cannulas was used in case of need. The rest of the operation was continued in conventional fashion via robotic arms. Less than mild aortic regurgitation was tolerated by using an additional transmitral sump catheter which improves visualization. Deairing is an essential and important part of the procedure. For this purpose, two suction catheters are used, one of them being kept in the left atrium and the other in left ventricle via mitral valve. both catheters are kept in place until the end of CPB and until no air is visible in TEE. Additionally, the left ventricular catheter helps in avoiding distention of the left ventricle.

3 | RESULTS

The perioperative demographics of the patients are presented in Table 1. Twenty-five patients underwent robotic-assisted surgery without X clamp, 11 (44.0%) men and 14 (56.0%) women with a mean age of 65.5 ± 20 years (range 6–92). Most patients were in New York Heart Association class ≥II (88.0%). The mean Logistic Euroscore value was 18.5 ± 22.3. The indications for avoiding cross-clamp were calcified aorta (n = 6, 24%) and mediastinal adhesions (n = 19, 76%). Mediastinal adhesions were related to redo surgery in 15 patients (60%) and 2 of them (8%) underwent robotic assistant surgery as a third time of intervention. The primary etiological pathologies for mitral or tricuspid valve were degeneration (n = 8, 32%), rheumatic valve (n = 4, 16%), infective endocarditis (n = 3, 12%), ischemia (n = 1, 4%), functional failure (n = 2, 8%), and dysfunctional prosthesis (n = 3, 12%). The type of operations are detailed in Table 2 and these were mitral valve repair/replacement, tricuspid valve repair/replacement, Cryoablation, ASD closure, and pericardiectomy. The combined procedure was performed in six patients (24%). CPB times were 141.5 ± 47 (minimum 77–maximum 252) min. The perioperative complications are presented in Table 3. Mean drainage was 337 ± 350 ml, and one patient underwent revision due to bleeding. Autotransfusion was used in all patients. There was no case of conversion to open thoracotomy or sternotomy. Hemiparesis was observed in one patient who underwent mitral valve repair and tricuspid valve replacement as a redo procedure; however, recovered

TABLE 1 Perioperative characteristics of patients

Demographics	Minimum–Maximum	Mean–*SD*
Age	6–92	65.5 ± 20
Log Euroscore	2–82	18.5 ± 22.3
EF (%)	40–72	62.4 ± 5.3
LVEDD (cm)	4.3–6.3	6.6 ± 7.4
CPB duration (min)	77–252	141.6 ± 47.1
ICU Stay (h)	2–138	34 ± 36.2
	n = 25	%
Female	14	56
NYHA Class 3–4	13	52
COPD	3	12
Hypertension	6	24
CAD	12	48
Preoperative AF	12	48

Abbreviations: AF, atrial fibrillation; CAD, coronary artery disease; CPB, cardiopulmonary bypass; COPD, chronic obstructive pulmonary disease; EF, ejection fraction; LVEDD, left ventricular end-diastolic dimension; NYHA, New York Heart Association.

within 3 months of follow-up. Two patients with 78.2 and 81.9 Euroscore values had mesenteric ischemia and multiorgan failure, respectively, and died at postoperative period (8%).

4 | DISCUSSION

Our study demonstrated that a robotic-assisted approach without aortic cross-clamping may provide reasonable perioperative outcomes in a specific group of patients undergoing intracardiac repair. Right-sided surgery via robotic assistance provides excellent exposure to the mitral valve or right atrial heart pathologies while

TABLE 2 Types of robotic-assisted operations performed without aortic cross-clamping

Repair techniques	*n* = 25	%
Tricuspid valve replacement	7	28
Mitral valve repair	4	16
Mitral valve replacement	4	16
Atrial septal defect repair	3	12
Mitral valve replacement + cryoablation	2	8
Mitral valve replacement + tricuspid valve repair	2	8
Tricuspid valve repair	1	4
Mitral valve repair + tricuspid valve replacement	1	4
Pericardiectomy	1	4

TABLE 3 Perioperative complications

Perioperative complications	*n*	%
Neurological deficit		
• Permanent	0	0
• Transient	1	1.7
Revision for bleeding	1	4
New onset atrial fibrillation	4	16
Postpericardiotomy syndrome	2	8
Pleural effusion needs drainage	2	8
Renal failure needs dialysis	2	8
Infective endocarditis	1	4
Mesenteric ischemia	1	4
Mortality	2	8

surgery with ventricular fibrillation eliminates extensive mediastinal dissection to place aortic clamp during redo surgery. Furthermore, this approach may prevent potential complications of aortic cross-clamping such as cerebral thromboemboli, and may avoid the complications of repeat sternotomy including catastrophic reentry into the heart and massive bleeding or injury to previous bypass grafts.

Although right-sided cardiac surgery via thoracotomy is not a new technique,[3] robotic-assisted intracardiac repair without cross-clamping was not reported in a large group of patients previously. The concerns of non-cross-clamping technique were related to the risk of air emboli and the consideration of suboptimal blood and oxygen supply to subendothelium of myocardium during operation.[4] In a study conducted by Svensson et al.,[5] in which the risks of redo mitral valve surgery was determined, right-sided thoracotomy comparing to median sternotomy was associated with a higher occurrence of stroke. They assumed the accidental ejection of air emboli and thromboemboli related to femoral arterial cannulation were the reasons for stroke during mitral surgery via thoracotomy.

In our experience, the strategy to overcome the complication of air emboli which may cause cerebral injury, myocardial dysfunction, and dysrhythmias the heart was fibrillated spontaneously due to moderate hypothermia or via electrical pulse before atriotomy. Minimally invasive cardiac surgery and especially robotic surgery do not permit standard deairing maneuvers related to docked arms which may injure the thoracic organs during these maneuvers. The use of CO_2 in minimal invasive cardiac surgery becomes more important compared with open cardiac surgery, continuous CO_2 insufflation (5 L/min) was used through the operation in our experience. Also, the left heart was kept empty by using an extra venting sucker cross the mitral valve to prevent distension of left ventricular and also for deairing before closing the atriotomy.

Conversely, femoral arterial cannulation was achieved via the Seldinger technique under TEE guidance to prevent stroke due to aortic dissection. In case of severe femoral or iliac artery calcification,

arterial cannulation was performed via the axillary artery, which is less prone to calcification.

The other group of patients had right atrial pathologies (n = 11; ASD = 3, tricuspid valve: 8) in our study. Although ASD can be treated with percutaneous devices with a low rate of early postprocedural complications, in patients with unfavorable anatomy or inappropriate type of ASD, defects are not suitable for transcatheter closure and these pathologies can be repaired totally endoscopically with robotic assistance. Moreover, there are important complications of transcatheter ASD closure including device migration, malposition, cardiac erosion, or perforation leading to tamponade, atrioventricular (AV) block, and bacterial endocarditis. Since the surgical technique does not require implantation of any prosthetic material, it may offer patients a safe long term outcome that is free from device-related complications.[2]

Robotic-assisted tricuspid valve repair or replacement without cross-clamping may also provide some other advantages. Damage to the AV node from sutures passed through the septal part of the tricuspid annulus can be recognized from development of an AV block and can be immediately rectified. This relieves the necessity for pacemaker implantation.

However, the present study has potential limitations. First of all, the study is retrospective, nonrandomized by nature and contains a limited number of patients. The types of operations are in a variety. All these mentioned reasons prevent direct conclusions from this study.

Finally, robotic-assisted cardiac surgery without cross-clamping may provide reasonable outcomes in patients with severe aortic calcification or mediastinal adhesions undergoing intracardiac repair. These acceptable outcomes may encourage surgeons to perform this approach in an appropriate group of patients.

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