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Case Series

Minimally Invasive Mitral Valve Surgery Using a Cold Fibrillatory Cardiac Arrest Technique in Patients With Prior Cardiac Surgery

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Abstract

Objective: Minimally invasive mitral valve surgery (mini-MVS) is typically reserved for patients who have not undergone open cardiac surgery. In the reoperative setting, using intrapericardial dissection for cross-clamping the aorta through a minimally invasive approach can be difficult and, at times, risky. Cold fibrillatory cardiac arrest (CFCA) with systemic cardiopulmonary bypass without cross-clamping is a well-described technique; however, data about its safety for patients who undergo reoperative mini-MVS are limited.

Methods: Data for 34 patients who underwent reoperative mini-MVS with CFCA from March 2017 to March 2022 were reviewed retrospectively. A mini right thoracotomy (n = 30) or robotic (n = 4) approach was used. Systemic hypothermia was induced to a target temperature of 25 °C.

Results: Patient mean (SD) age was 64.5 (9.6) years, and 15 of 34 (44.1%) patients were women. Of those 34 patients, 23 (67.6%) had severe regurgitation, and 11 (32.4%) had severe stenosis. Before mini-MVS, 28 patients had undergone valve surgery, and 8 had undergone coronary artery bypass graft surgery. The mitral valve was repaired in 5 of 34 (14.7%) and replaced in 29 of 34 (85.3%) patients. No difference was observed in preoperative and postoperative left ventricular function ($P = .82$). In 1 patient, kidney failure developed that necessitated dialysis. No postoperative stroke or mortality at 30 days occurred.

Conclusion: Mini-MVS with CFCA is well tolerated in patients with prior cardiac surgery. Myocardial function was not impaired, nor was the risk of stroke increased in this cohort, indicating that CFCA is a safe alternative in this high-risk population.

Keywords: Arrest, cardiac; mitral valve; reoperation; surgery, cardiac

Introduction

The rate of reoperative cardiac surgery in patients who have previously undergone cardiac surgery is estimated to be 10% and continues to increase. This increase can be attributed to advances in anesthesia and postoperative management and to an aging population.[1] In addition, cases of reoperative cardiac surgery have become increasingly complex. Challenges include safely obtaining access without injuring any of the vascular structures (eg, the brachiocephalic vein, right ventricle, aorta) or a patent bypass graft lying directly behind the sternum. In an analysis of the Society of Thoracic Surgeons (STS) national database, the STS-predicted risk of mortality in this group of reoperative patients was 8%, with 20% having an STS-predicted risk of mortality greater than 10%.[2]

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Minimally invasive mitral valve surgery (mini-MVS) has evolved over the past 3 decades and has been shown to be a safe approach with good clinical outcomes. Perioperative morbidity and mortality rates are comparable between high-risk patients who undergo mini-MVS and patients who undergo MVS via a sternotomy approach.[3,4] In addition, the use of mini-MVS has consistently been associated with a reduced incidence of blood transfusions, decreased postoperative pain, and shortened intensive care unit stays and recovery times.[5]

Myocardial protection strategies include standard cardioplegia solution with aortic cross-clamping and beating heart as well as ventricular fibrillatory arrest without cross-clamping. Cold fibrillatory cardiac arrest (CFCA) is a strategy of myocardial protection that has been shown to be as safe as hypothermic cardioplegic arrest.[6] Furthermore, its use avoids the risks associated with aortic cross-clamping in the setting of dense intrapericardial adhesions or calcified aorta as well as potential problems related to cardioplegic arrest in the presence of a patent left internal mammary artery graft.

Data are limited on the efficacy and safety of performing reoperative mini-MVS with the CFCA technique. Potential drawbacks of using CFCA include poor visualization caused by increased blood return in the operative field, the inability to interrogate valve competency with high-pressure irrigation, coagulopathy from maintaining hypothermia, and an elevated incidence of stroke caused by air embolism. This article describes a single-center experience with reoperative mini-MVS and the CFCA technique.

Key Points

- Redo sternotomy for MVS can be extremely challenging, carrying an 8% STS-predicted mortality risk.
- The 30-day survival and stroke outcomes in this cohort showed that mini-MVS with CFCA is a safe alternative approach in a redo operative setting.
- In this patient series, CFCA did not compromise left ventricular function.

Abbreviations and Acronyms

CFCA	cold fibrillatory cardiac arrest
mini-MVS	minimally invasive mitral valve surgery
STS	Society of Thoracic Surgeons

Patients and Methods

From March 2017 to March 2022, 34 patients at Baylor College of Medicine with a history of cardiac surgery underwent mini-MVS with CFCA. All patients had symptomatic mitral valve disease, despite optimal medical management. Patient demographics, baseline characteristics, and in-hospital outcomes were defined and coded according to the STS adult cardiac surgery database (versions 2.6-2.8).

Patient data were collected and reviewed retrospectively. Categorical variables are reported as number (%), and continuous variables are reported as mean (SD) or median (IQR), as appropriate. Institutional review board approval (Baylor College of Medicine, IRB H-43621, October 19, 2018, to October 31, 2026) was obtained for this study. The requirement for patient consent was waived because of the retrospective nature of this study.

Surgical Technique

Patients are typically placed in a supine position, with a pad slightly elevating the right chest. After the induction of general anesthesia, a double-lumen endotracheal tube is placed, along with arterial monitoring, central lines, a pulmonary artery catheter, and external cardiac defibrillator pads (Zoll Medical Corp). A pacing lead is inserted percutaneously via the right internal jugular vein to the right ventricle and connected to a pacing or defibrillation generator box. The surgical approach used for most patients in this study was a right third intercostal mini-anterior thoracotomy (n = 30). In 4 cases, a 3-port robotic approach was used, with a 5-cm access incision in the fourth intercostal space. Peripheral access for cardiopulmonary bypass was established through the femoral vessels via a small inguinal incision. After minithoracotomy, dissection was limited to what was needed to free adhesions and access the intra-atrial groove. Patients were cooled to a temperature of 25 °C. Cold ventricular fibrillation was used in all cases. Pacing wires were used to induce ventricular fibrillation in patients when cooling alone was unsuccessful. A vertical left atriotomy approach was used for mitral valve repair or replacement. In all patients, a left ventricular vent was used, with an aortic root vent for deairing.

Transesophageal echocardiography was used to assess biventricular function and valve repair or replacement results and to guide deairing from the left heart before the patient was weaned off bypass upon completion of the procedure.

Results

A total of 34 consecutive patients with a history of cardiac surgery via a sternotomy (n = 33) or right thoracotomy (n = 1) approach underwent mini-MVS with CFCA at Baylor College of Medicine. Basic patient demographic characteristics and preoperative comorbidities are listed in Table I. The mean (SD) age was 64.5 (9.6) years, and 16 of 34 (47%) patients were men.

Previous cardiac surgeries included prior MVS (repair or replacement) in 16 patients, aortic valve replacement in 12 patients, and combined aortic valve replacement and coronary artery bypass graft in 8 patients. Indications for mini-MVS were severe symptomatic degenerative mitral valve regurgitation in 23 of 34 (67.6%) patients and severe mitral valve stenosis in 11 of 34 (32.4%) patients. All procedures were elective. Cardiopulmonary bypass was established via femoral artery, with vein cannulation and CFCA at 25 °C. The mean (SD) cardiopulmonary bypass time was 160.2 (49.8) minutes, and the mean (SD) CFCA time was 106.4 (38.7) minutes. Operative details are provided in Table II.

Of the 34 patients who underwent mini-MVS, 5 underwent mitral valve repair, and 29 underwent mitral valve replacement. In 25 of the 29 patients who underwent mitral valve replacement, a bioprosthetic valve was used, including 2 transcatheter aortic valves (Edwards Sapien 3) used in the mitral position because of severe mitral annular calcifications and 4 mechanical valves used because of the patient's young age or preference. Of the entire cohort, 5 (14.7%) patients underwent concomitant procedures: 2 left-sided surgical ablations and 3 tricuspid valve annuloplasties.

Left ventricular function, valve function, and presence of paravalvular leak were evaluated using intraoperative transesophageal echocardiography. Evidence of trace to mild paravalvular leak was observed in 2 of 34 (5.9%) patients. Severe paravalvular leak was seen in 1 patient with a history of 2 sternotomies after an Edwards (Sapien 3) 26-mm aortic valve was placed in the mitral position to treat severe mitral annular calcification. A paired *t* test was used to compare the mean preoperative ejection fraction with the mean postoperative ejection fraction in the group. No difference was observed between preoperative and postoperative left ventricular function (mean [SD] ejection fraction = 51.6% [8.373%] vs 52.17% [8.00%]; $P = .82$).

Postoperative complications are summarized in Table III. At 30 days, survival was 100%; however, 1 patient who was a high-risk septuagenarian man with multiple comorbidities and severe mitral annular calcifications did not survive to discharge after a protracted hospital course complicated by respiratory insufficiency, septicemia, and multisystem organ failure. One patient had preoperative chronic kidney disease that was complicated by postoperative acute on chronic kidney failure necessitating continuous kidney replacement therapy. No postoperative transient ischemic attacks or

TABLE I. Patient Demographics

Characteristic	All patients (N = 34)
Age, mean (SD), y	64 (9.6)
Women, No. (%)	18 (52.9)
Coronary artery disease, No. (%)	17 (50)
Previous myocardial infarction, No. (%)	6 (17.6)
New York Heart Association class, mean (SD)	2.2 (0.5)
Left ventricular ejection fraction, mean (SD), %	51.6 (8.4)
Diabetes, No. (%)	13 (38.2)
Hypertension, No. (%)	29 (85.3)
Stroke, No. (%)	8 (23.5)
Kidney failure, No. (%)	2 (5.9)
Chronic obstructive pulmonary disease, No. (%)	8 (23.5)
Severe mitral valve regurgitation, No. (%)	23 (67.6)
Severe mitral stenosis, No. (%)	11 (32.4)
Previous cardiac operations, No.	
Mitral valve repair	13
Mitral valve replacement	3
Aortic valve replacement	12
Coronary artery bypass graft	1
Combined aortic or mitral valve surgery and coronary artery bypass graft	8
Heart-lung transplantation, No.	1

TABLE II. Operative Data

Characteristic	All patients (N = 34)
Approach, No. (%)	
Mini-right thoracotomy	30 (88.2)
Robot assisted	4 (11.8)
Mitral valve procedure, No. (%)	
Mechanical mitral valve replacement	4 (11.8)
Bioprosthetic mitral valve replacement	25 (73.5)
Transcatheter mitral valve replacement	2 (5.8)
Mitral valve repair	5 (14.7)
Concomitant procedures, No. (%)	
Left-sided surgical ablation	2 (5.8)
Tricuspid valve replacement	3 (8.8)
Cardiopulmonary bypass time, mean (SD), min	160.2 (49.8)
Cold fibrillation time, mean (SD), min	106.4 (38.7)

TABLE III. Perioperative Data

Outcome	All patients (N = 34)
Postoperative left ventricular ejection fraction, mean (SD), %	52.17 (8)
Degree of paravalvular leak, No. (%)	
Trace-mild	2 (5.8)
Severe	1 (2.9)
Intensive care unit stay, median (IQR), d	2.2 (1.8-2.5)
Respiratory failure or tracheostomy, No. (%)	1 (2.9)
Kidney failure (hemodialysis), No. (%)	1 (2.9)
Stroke, No. (%)	0 (0)
30-d mortality, No. (%)	0 (0)
Survival to discharge, No. (%)	33 (97.0)

strokes were reported. Median intensive care unit stay was 2.2 days (IQR, 1.8-2.5 days). Of the 33 patients discharged, 32 (97.0%) were discharged within 14 days of their surgical date, and 1 (3.0%) was discharged on postoperative day 19.

Discussion

Redo cardiac surgery through a median sternotomy is typically associated with higher morbidity and mortality rates because of the risk of injury to major vascular structures or existing coronary bypass grafts.[1] Cardiac dissection may be limited at times by dense intrapericardial adhesions that can make exposure extremely challenging, compromise myocardial protection, and increase the incidence of coagulopathy. Isolated MVS in reoperative cases is associated with a 6.6% operative mortality risk, a 5.6% rate of kidney failure, and a 2.4% incidence of postoperative stroke.[2] Gill et al[7] reported an operative mortality rate of 14.2% for isolated mitral valve replacement in patients with a previous sternotomy.

Minimally invasive MVS through a right mini-thoracotomy incision can provide a direct, clear view of the posteriorly positioned mitral valve, especially with the use of a videoscope or robotic assistance, without extensive lysis of intrapericardial adhesions to free up the apex in the reoperative setting. Minimally invasive MVS has also been associated with shorter intensive care unit and hospital stays, fewer blood transfusions, and earlier recovery than a conventional sternotomy approach.[8,9]

Cold fibrillatory cardiac arrest is a readily available, safe alternative to cross-clamping and cold cardioplegia arrest. It maintains continuous coronary flow, especially in patients with previous patent coronary bypass grafts. Furthermore, compared with cross-clamping and cold cardioplegia arrest, CFCA was found to be associated with lower myocardial lactate accumulation, which confers added myocardial protection, especially in patients with severe left ventricular dysfunction.[10] Seeburger et al[1] reviewed their experience with mini-MVS via the same surgical approach. In their cohort of 181 patients, CFCA was used in 140 (77.3%) patients. The overall 30-day mortality rate was 6.6%, with low cardiac output syndrome developing in only 13 (7.2%) patients. In another study of robot-assisted mini-MVR and CFCA in 21 patients with prior sternotomy, the observed operative mortality rate was 6.2%, compared with the expected operative mortality rate of 6.6%. For

patients with a left ventricular ejection fraction of 20% or less, the observed mortality rate was 5.6%, compared with the expected mortality rate of 7.4%.[3] The rate of stroke associated with this technique varies. Gammie et al[4] reported a 3-fold elevated risk of stroke in patients who underwent less invasive mitral valve interventions with a fibrillatory heart. In a separate cohort, a stroke rate of 3% was reported.[11] In a comparison of the results of mitral valve reoperations performed at the Cleveland Clinic via a redo sternotomy or right thoracotomy incision (CFCA was used in 91% of patients), the rate of stroke was higher in the redo sternotomy group than in the right thoracotomy incision group (7.5% vs 2.7%).[12]

In this series, the mini-MVS with CFCA approach was found to be safe, with no perioperative mortality, no neurologic complications, a low incidence of kidney failure necessitating dialysis, and acceptable outcomes in this high-risk population. These findings can be attributed to several important factors. First, the operations were performed by surgeons with extensive experience in minimally invasive mitral valve techniques and a high level of comfort with operating on this patient population. Furthermore, the improved visualization provided by the right thoracotomy approach, especially with the introduction of the robotic systems, offers an additional advantage over the limited exposure afforded by a redo sternotomy. Meticulous deairing under transesophageal echocardiographic guidance is key to mitigating the risk of stroke observed in other studies. A left ventricular vent, a 14-gauge Angiocath needle (Becton Dickinson) acting as an aortic root vent, and carbon dioxide flowing at a rate of 6 L/min to flood the operative field are used to achieve this result. In some instances, an additional left ventricular vent may be placed to address stubborn air pockets. An important consideration is to avoid testing the valve after repair or replacement by insufflating the left ventricle with normal saline, which can introduce debris and air into the aorta. Rather, the ventricle is allowed to fill retrograde. A right-angled clamp inserted underneath the anterior leaflet at the anterolateral commissure can render the aortic valve incompetent for this purpose.

Study Limitations

This study is subject to the inherent limitations of a retrospective study in which data were collected from a small cohort without a control group. In addition, this study is subject to the limitations associated with minimally invasive approaches, such as surgeon preference and experience, the steep learning curve associated with new minimally invasive techniques, and the inability to perform a procedure combined with coronary artery bypass or aortic valve replacement.

Conclusion

These findings indicate that mini-MVS with CFCA in patients who underwent prior cardiac surgeries is a safe and effective technique in this high-risk patient population.

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