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Original Article

Outcomes and Risk Factors Associated with Pericardiectomy in Patients with Constrictive Pericarditis: A Retrospective Study from China

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Purpose: Pericardiectomy is the definitive treatment option for constrictive pericarditis and is associated with a high prevalence of morbidity and mortality. However, information on the associated outcomes and risk factors is limited. We aimed to report the mid-term outcomes of pericardiectomy from a single center in China.

Methods: We retrospectively reviewed data collected from patients who underwent pericardiectomy at our institute from April 2018 to January 2023.

Results: Eighty-six consecutive patients (average age, 46.1 ± 14.7 years; 68.6 men) underwent pericardiectomy through midline sternotomy. The most common etiology was idiopathic (n = 60, 69.8%), and 82 patients (95.3%) were in the New York Heart Association function class III/IV. In all, 32 (37.2%) patients underwent redo sternotomies, 36 (41.9%) underwent a concomitant procedure, and 39 (45.3%) required cardiopulmonary bypass. The 30-day mortality rate was 5.8%, and the 1-year and 5-year survival rates were 88.3% and 83.5%, respectively. Multivariable analysis revealed that preoperative mitral insufficiency (MI) ≥moderate (hazard ratio [HR], 6.435; 95% confidence interval [CI] [1.655–25.009]; p = 0.007) and partial pericardiectomy (HR, 11.410; 95% CI [3.052–42.663]; p = 0.000) were associated with increased 5-year mortality.

Conclusion: Pericardiectomy remains a safe operation for constrictive pericarditis with optimal mid-term outcomes.

Keywords: constrictive pericarditis, pericardiectomy, surgical outcomes, mitral insufficiency

Introduction

Constrictive pericarditis (CP) is characterized by impaired diastolic filling of the ventricles due to pericardial disease.[1–4] The resulting cardiac dysfunction can lead to varying degrees of heart failure, with the operative mortality risk ranging from 0% to 19%.[5–13] Nowadays, with improvements in living standards and health care, the main type of CP has changed from tuberculous to idiopathic CP.[1,2] However, In Guangxi and Guangdong provinces, south of China, the incidence of tuberculous pericarditis is still high, ranging from 23.0% to 52.5%.[14,15]

CP requires surgical treatment upon diagnosis to prevent further deterioration of clinical manifestations.

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Nevertheless, regardless of the evolving primary cause of pericarditis, total pericardiectomy remains highly effective and potentially restorative in alleviating patient symptoms, as well as in preventing disease progression and mortality.[8,16] However, surgical removal of the pericardium has been associated with very high rates of early morbidity and mortality. To avoid complications, pericardiectomy must be as complete as is technically feasible and should be performed in highly experienced centers.[1] Meanwhile, the proportion of redo sternotomies has gradually increased due to former subtotal pericardiectomy.[8,17] Although the outcomes and risk factors associated with pericardiectomy have been reported, the information is limited, especially for recent procedures conducted in China.[14,15,17–19]

To address these needs, this study aimed to analyze the short- and mid-term outcomes of surgical pericardiectomy in 86 patients treated in our hospital from April 2018 to January 2023 and followed up for a median length of 12.0 months (the longest was 58 months). Our results suggest that pericardiectomy remains a safe surgical method for CP, yielding favorable mid-term results, with preoperative MI ≥moderate and partial pericardiectomy identified as notable risk factors associated with reduced mid-term survival.

Materials and Methods

Study cohort

The surgical database of Peking University International Hospital in Beijing, China, was constructed prospectively and studied retrospectively. A total of 87 patients were diagnosed with CP between April 2018 and January 2023. One patient, with a history of total pericardiectomy, who underwent mitral valve replacement because of rheumatic mitral valve disease, was excluded. Other 86 patients who underwent pericardiectomy through midline sternotomy were all included.

Data collection and follow-up

The study protocol was approved by the Institutional Review Board with patient consent waived at Peking University International Hospital. Patient information was anonymized and de-identified before analysis. Medical records, including demographic data, preoperative characteristics, operative procedures, and perioperative and postoperative data, were reviewed. All data were collected by trained clinical research staff and were double-entered into computer databases.

All surgical patients discharged alive from the hospital are required to return for an outpatient follow-up visit 3 months after surgery and then once every year for an outpatient follow-up visit. In addition, all patients were contacted by telephone again by the research staff using standard procedures and forms. Follow-up results were available for all patients.

Definition

The clinical diagnosis was confirmed by echocardiography and supplemented by chest computed tomography or cardiac magnetic resonance imaging. Patients with a history of prior chest radiation were defined as having post-radiation pericarditis. Patients with a history of prior cardiac surgery were defined as having postoperative pericarditis. Additional possible etiologies included tuberculosis, hemopericardium, and tumor related. Patients who could not be classified in any of these groups were considered to have idiopathic pericarditis.

Treatment

Preoperative preparation

(1) Antiinfection therapy for primary infectious diseases that may be present leading to CP; (2) diuretic therapy was used to alleviate fluid retention in patients, and diuretic effects were assessed by monitoring changes in body weight; (3) vitamin K1 was used to improve the patients' coagulation function the day before surgery; and (4) with the guidance of the cardiac rehabilitation physician, all patients underwent respiratory training before and after surgery.

Surgical technique

Because carrying out decortications across the sternum and onto the right atrium and venae cavae through left anterolateral thoracotomy is difficult, all patients in our center underwent pericardiectomy through median sternotomy. We use the electrosurgical equipment (VIO 300S, Monopolar, Forced Coag; ERBE, Germany) to perform pericardiectomy. When separating the mediastinal pleura and pericardium, the power of the electrotome is 40 W with effect 4, and when separating the pericardium and myocardium, the power of the electrotome is 20 W with effect 4. When removing the stripped pericardial tissue, we applied DRY CUT mode with a power of 80 W with effect 4. If the pericardial tissue was extremely hard due to severe calcification, we removed the pericardial tissue with scissors or wire cutters. Total pericardiectomy was defined as wide excision of the pericardium anteriorly between the two phrenic nerves and from the great arteries superiorly to the diaphragm inferiorly, posterior to the left phrenic nerve to the left pulmonary veins, and including the pericardium on the diaphragmatic and posterior surfaces of the ventricles. The atria and venae cavae were decorticated to the maximum extent. The extent of pericardiectomy followed the standard procedure unless it was not technically feasible. We preferred to perform pericardiectomy off-pump first (**Supplemental Video**) before the cardiopulmonary bypass (CPB) was used, regardless of the reason.

The specific technique of operation was described as follows:

(1) The separation of pleura and parietal pericardium can extend beyond the phrenic nerve on the right side; on the left side, the phrenic nerve often cannot be initially exposed due to the limitations of the surgical field.

(2) Dissection begins between the aorta and pulmonary artery, with an incision extending cephalad to the reflection of the pericardium and caudally to the apex cordis.

(3) Use vascular forceps to pull the pericardium, assisting in exposing the gap between the heart and the pericardium. First, dissect the pericardium of the partial anterior wall of the right ventricle, the anterior wall of the left ventricle, and part of the lateral wall of the left ventricle with the electrotome.

(4) During the dissection of the pericardium, pay attention to separating the parietal pericardium and left pleura, expose the left phrenic nerve, and extend the dissection beyond the left phrenic nerve. However, due to the difficulty in lifting the apex cordis, the pericardium over the apex and posterior wall of the left ventricle are temporarily not dissected.

(5) Dissect the pericardium covering the anterior wall of the right ventricle, right atrium, superior and inferior vena cava, and most of the diaphragmatic surface (the pericardium over the apex and part of posterior wall of the left ventricle are temporarily retained).

(6) Finally, dissect the pericardium over the apex and the posterior wall of the left ventricle. Pull the pericardium toward the patient's right shoulder to free the adhesions between the apex of the heart, left pleura, and left diaphragm. Then, pull the pericardium in the opposite direction to dissect the pericardium over the apex and the posterior wall of the left ventricle.

(7) Throughout the dissection process, pay attention to the infusion of dopamine and diuretics, and control the heart's volume by adjusting the operating table to a head-high and feet-low position.

In most cases, CPB was used owing to dense adhesions to the epicardium or hemorrhage when total pericardiectomy could not be undergone off-pump. In addition, the use of CPB depended on concomitant procedures. An atrioventricular valve repair or replacement was performed according to the surgeons' experience.

Statistical analysis

Continuous variables were expressed as median and interquartile range or mean ± standard deviation (SD). Categorical variables were reported as frequencies and percentages and were compared using the chi-square test or Fisher's exact test. Statistical comparisons between the initial, early postoperative, and follow-up data were performed using paired T-test or nonparametric test. Survival was calculated using the Kaplan–Meier method and compared using the log-rank test. To further analyze survival, multivariable Cox proportional hazards regression models were constructed. $p < 0.05$ was considered to indicate statistical significance. All statistical analyses were performed using Statistical Package for Social Sciences (SPSS) software version 24.0 (SPSS Inc, Chicago, IL, USA).

Results

Perioperative data

From April 2018 to January 2023, 86 consecutive patients underwent pericardiectomy. The average age was 46.1 ± 14.7 years (range, 6–67 years). Four (4.7%) patients were under 18 years of age. There were 27 women (31.4%). The etiologies were idiopathic (n = 60, 69.8%), tuberculosis (n = 18, 20.9%), hemopericardium (n = 4, 4.7%), post-radiation (n = 3, 3.5%), and tumor (n = 1, 1.2%). Most patients (n = 82, 95.3%) present with symptoms of heart failure (New York Heart Association [NYHA] function Class III or IV) with a long course of disease (34.7 ± 71.4 months; range, 1–504 months). Systemic venous congestion symptoms were as follows: dyspnea (87.2%), peripheral edema (87.2%), abdominal distension (58.1%), ascites (44.2%), and pleural effusion (44.2%). Diuretics were the best medical therapy in the perioperative period, and patients lost 4.3 ± 3.1 kg of body weight before surgery and showed an improvement in symptoms. Preoperatively, 40 of 86

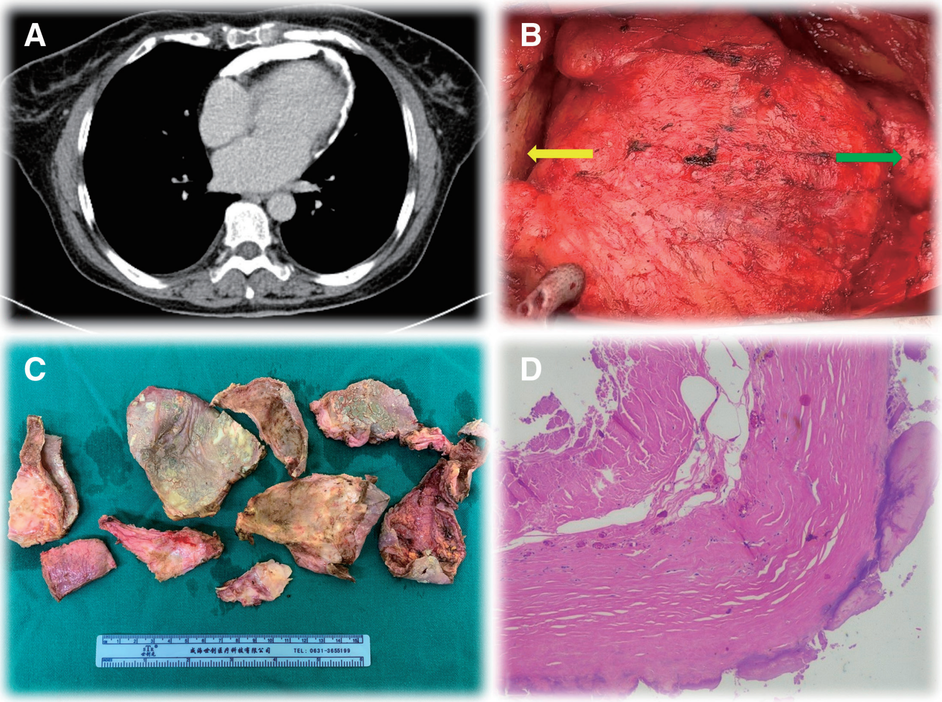

Fig. 1 (**A**) Chest CT showed pericardium thickened and calcified obviously; (**B**) The heart after pericardiectomy (the yellow arrow is the diaphragm and the green arrow is the ascending aorta); (**C**) Stripped pericardial tissue with scale; (**D**) Under the 10× microscope, the pathological section of the pericardium showed proliferation of interstitial fibrous tissue accompanied by noticeable hyaline degeneration, calcification, and vascular dilation congestion. CT: computed tomography

patients (46.5%) had atrial fibrillation. Echocardiography revealed a thickened pericardium in all patients (**Fig. 1**). Preoperative computed tomography (CT) was done in all patients, and pericardial calcification was found in 68 patients (79.1%) (**Table 1**, **Fig. 1**). As a result of CP, the heart, especially the atria, was significantly enlarged (cardio-thoracic ratio 0.52 ± 0.06). Baseline characteristics are summarized in **Table 1**.

All patients underwent pericardiectomy through median sternotomy. Total pericardiectomy was performed in 77 (89.5%) patients. In all, 32 (37.2%) patients had undergone at least one prior sternotomy. Most patients did not require CPB (n = 47, 54.7%), and of the 39 who did, 36 (92.3%) patients underwent a concomitant procedure (mitral valvuloplasty [MVP], n = 27; mitral valve replacement [MVR], n = 3; tricuspid valvuloplasty [TVP], n = 33; tricuspid valve replacement [TVR], n = 1; aortic valve replacement [AVR], n = 1). Central venous pressure decreased significantly after surgery (5.6 ± 2.7 vs. 15.1 ± 5.6, p <0.001). Most commonly, early morbidities included renal dysfunction (n = 45, 52.3%), pneumonia (n = 22, 25.6%), and new atrial fibrillation (n = 14, 16.3%) (**Table 2**).

Perioperative mortality

Thirty-day mortality occurred in five patients (5.8%). The causes of death were intraoperative acute right heart failure (n = 1), respiratory failure (n = 1), acute renal failure and hyperkalemia (n = 1), acute arterial embolism in both lower limbs (n = 1), and sudden death with unknown cause (n = 1).

Mid-term mortality

At the last follow-up, 74 patients were alive. The patients had a significant improvement in their NYHA status from 3.2 ± 0.5 to 1.2 ± 0.4 (p <0.001). Survival rates at 1 year and 5 years were 88.3% and 83.5%, respectively. Post-radiation pericarditis (odds ratio [OR], 16.246; 95% CI [3.972–66.443], p = 0.002), surgical history of lung cancer (OR, 7.195; 95% CI [1.538–33.650], p = 0.042), hypoproteinemia (OR, 6.152, 95% CI [1.345–28.128], p = 0.006), preoperative MI ≥moderate (OR, 4.452, 95% CI [1.340–14.795], p = 0.011), need for CPB (OR, 4.523, 95% CI [1.357–15.082], p = 0.028), partial pericardiectomy (OR, 8.171, 95% CI [2.477–26.952], p = 0.002), re-intubation (OR, 10.657, 95% CI [2.768–41.028], p = 0.005), and tracheotomy (OR, 22.410, 95% CI

Table 1 Baseline characteristics

Characteristic [mean ± SD or frequency (%)]	Total population (n = 86)
Age (years)	46.1 ± 14.7
Female (n, %)	27 (31.4)
BMI (kg/m^2)	23.5 ± 3.5
BSA (m^2)	1.75 ± 0.20
NYHA functional class	
II	4 (4.7)
III	57 (66.3)
IV	25 (29.1)
CHD	5 (5.8)
Hypertension	8 (9.3)
Hyperlipidemia	4 (4.7)
Diabetes	7 (8.1)
Hemoglobin (g/dL)	135.3 ± 21.2
Renal dysfunction	5 (5.8)
TBIL (μmol/L)	26.6 ± 13.5
DBIL (μmol/L)	12.8 ± 7.3
ALT (U/L)	19.8 ± 13.9
AST (U/L)	27.8 ± 12.4
ALP (U/L)	115.9 ± 48.6
GGT (U/L)	101.7 ± 72.4
PT (s)	14.4 ± 3.2
INR	1.3 ± 0.3
ALB (g/L)	38.9 ± 7.1
NT-proBNP (pg/mL)	502.4 ± 670.8
Atrial arrhythmia	40 (46.5)
CTR	0.52 ± 0.06
LAD (mm)	48.8 ± 11.7
LVEDD (mm)	40.7 ± 5.6
EF (%)	62.9 ± 8.8
SPAP (mmHg)	32.75 ± 9.5
MI (≥moderate)	28 (32.6)
TI (≥moderate)	38 (44.2)
Pericardial calcification	
None	18 (20.9)
Mild	31 (36.0)
Severe	37 (43.1)

BMI: body mass index; BSA: body surface area; NYHA: New York Heart Association; CHD: coronary heart disease; TBIL: total bilirubin; DBIL: direct bilirubin; ALT: alanine transaminase; AST: aspartate aminotransferase; ALP: alkaline phosphatase; GGT: gamma-glutamyl transferase; PT: prothrombin time; INR: international normalized ratio; ALB: albumin; BNP: brain natriuretic peptide; CTR: cardio-thoracic ratio; LAD: left atrial dimension; LVEDD: left ventricular end-diastolic dimension; EF: ejection fraction; SPAP: systolic pulmonary artery pressure; MI: mitral insufficiency; TI: tricuspid insufficiency

Table 2 Intra-operative and postoperative information for pericardiectomy

Variable [mean ± SD or frequency (%)]	Total population (n = 86)
Intraoperative information	
Median sternotomy	86 (100)
Cardiopulmonary bypass	39 (45.3)
Concurrent operation	
MVP	27 (31.4)
MVR	3 (3.5)
TVP	33 (38.4)
TVR	1 (1.2)
AVR	1 (1.2)
CVP change, mm Hg	
Preoperative CVP	15.1 ± 5.6
Postoperative CVP	5.6 ± 2.7
Postoperative complications	
Renal dysfunction	45 (52.3)
CRRT	4 (4.7)
New atrial fibrillation	14 (16.3)
Malignant arrhythmia	3 (3.5)
Reoperation for bleeding	2 (2.4)
Low output syndrome	4 (4.7)
Lower extremities arterial embolism	1 (1.2)
Pneumonia	22 (25.6)
Tracheotomy	3 (3.5)
Re-intubation	4 (4.7)
Stroke	1 (1.2)
Intra-Aortic balloon pump	2 (2.4)
Intensive care unit stay, days	4.1 ± 6.8
Hospital stay, days	19.3 ± 9.7
30-day mortality	5 (5.8)

MVP: mitral valvuloplasty; MVR: mitral valve replacement; TVP: tricuspid valvuloplasty; TVR: tricuspid valve replacement; AVR: aortic valve replacement; CVP: central venous pressure; CRRT: continuous renal replacement therapy

[5.212–96.361], p = 0.002) were risk factors in the univariate model (**Supplemental Table 1**). Preoperative MI ≥moderate (HR, 6.435; 95% CI [1.655–25.009]; p = 0.007) and partial pericardiectomy (HR, 11.410; 95% CI [3.052–42.663]; p <0.001) were identified as independent risk factors in the multivariate model (**Supplemental Table 2**).

Partial pericardiectomy

The reason for partial pericardiectomy was dense adhesions to the epicardium. The mortality rate in 77 patients who underwent radical pericardiectomy was significantly lower than in the 9 patients who underwent partial pericardiectomy (7 of 77, 9.1%, vs. 5 of 9, 55.6%, p = 0.002). Meanwhile, we noticed that the reason for redo sternotomies (n = 32) was partial pericardiectomy.

MI ≥moderate

Compared with patients with MI <moderate, those with MI ≥moderate had a higher incidence of preoperative atrial fibrillation (67.9% vs. 36.2%, p = 0.010), larger left atrium dimension (53.5 ± 13.7 mm vs. 46.4 ± 9.9 mm, p = 0.008), and lower ejection fraction value (60.0 ± 9.0 vs. 64.3 ± 8.4, p = 0.035). As patients with MI ≥moderate had a higher rate of mitral valve intervention (60.7% vs. 22.4%, p <0.010), the operation duration was also longer (324.0 ± 118.3 min vs. 237.7 ± 92.8, p <0.001). MVP (90.0%) was the dominant surgical procedure for the concomitant mitral valve intervention. Meanwhile, the proportion of MVP was higher in patients with MI ≥moderate (53.6% vs. 20.7%, p = 0.003). The left atrium dimension in patients with MI ≥moderate (53.8 ± 14.3 mm vs. 45.6 ± 13.1 mm, p <0.001) and those with MI <moderate (46.7 ± 10.1 mm vs. 39.9 ± 8.9 mm, p <0.001) both significantly reduced after pericardiectomy. However, the left atrium dimension was still significantly greater in patients with MI ≥moderate compared with those with MI <moderate (45.6 ± 13.1 mm vs. 39.9 ± 8.9 mm, p = 0.024) after pericardiectomy. In addition, the postoperative complication rate in patients with MI ≥moderate is significantly higher, including CRRT (14.3% vs. 0.0%, p = 0.010), malignant arrhythmia (10.7% vs. 0.0%, p = 0.033), tracheotomy (14.3% vs. 0.0%, p = 0.010), re-intubation (10.7% vs. 0.0%, p = 0.033), hospital stay (23.5 ± 13.6 days vs. 17.3 ± 6.2 days, p = 0.028), and overall mortality (26.6% vs. 6.9%, p = 0.016) (**Table 3**).

The overall mortality for the overall study population was 14.0%, but it was significantly higher among patients with MI ≥moderate (28.6%) than in those with MI <moderate (6.9%) (**Fig. 2**). Multivariate analysis revealed that preoperative MI ≥moderate (HR, 6.435; 95% CI [1.655–25.009]; p = 0.007) was associated with increased overall mortality. Mitral valve intervention was not a predictor of overall mortality. Among the 28 patients with MI ≥moderate at the time of pericardiectomy, 17 (60.7%) had a mitral valve intervention and 11 (39.3%) did not. Mitral valve operation was not performed in 11 patients because of serious adhesion and difficulty in mitral valve exposure. Intraoperative transesophageal echocardiography (TEE) showed that MI improved in seven patients and remained moderate or above in 4 patients after pericardiectomy. Among the 11 patients, 5 died, 1 underwent reoperation due to low cardiac output, and 5 had mild or less mitral regurgitation during follow-up. Mortality was decreased among patients with MI ≥moderate with mitral valve intervention; however, it was not significantly different compared with that of the patients without mitral valve intervention (3 of 17, 37.5%, vs. 5 of 11, 45.5%; p = 0.200).

Discussion

Our result suggests that pericardiectomy remains a safe and effective method for managing CP, demonstrating favorable mid-term results. Preoperative MI ≥moderate and partial pericardiectomy were significant risk factors for decreased mid-term survival.

Mortality

Surgery for CP was associated with a significant risk based on the poor preoperative patient status. The 30-day perioperative mortality was 6% (8 of 132), and the overall mortality was 21.8% in 132 patients evaluated at Mayo Clinic.[20] Biçer et al. reported a perioperative mortality of 2.1% (1 of 47 patients) and a late mortality of 23.4% (11 of 47 patients).[21] Similarly, Bertog et al. reported an in-hospital mortality of 6%.[22] In the present study, the patients had a high overall mortality of 14.0%, which was attributed to serious conditions. Most patients (95.4%) present with symptoms of heart failure (NYHA function Class III (66.3%) or IV (29.1%)) with a long disease course (34.7 ± 71.4 months). Reportedly, the second operation is responsible for the high mortality risk, and the need for CPB predicts the 30-day mortality.[4,21] In our series, 32 (37.2%) patients underwent a redo sternotomy due to previous partial pericardiectomy, 36 (41.9%) underwent a concomitant valve procedure, and 39 (45.3%) required CPB. All these unfavorable conditions posed challenges to postoperative management.

In our study, post-radiation pericarditis, surgical history of lung cancer, hypoproteinemia, preoperative MI ≥middle, need for CPB, partial pericardiectomy, re-intubation, and tracheotomy were identified as risk factors for overall mortality in the univariate model. The multivariable model identified preoperative MI ≥moderate and partial pericardiectomy as independent risk factors. Meanwhile, mortality risk factors were evaluated by some cardiac centers. The need for CPB, sub-total pericardiectomy, radiation-induced CP, and preoperative regurgitation have been identified as risk factors for overall mortality.[9,14,20,23]

Table 3 Preoperative, intra-operative, and postoperative data of patients with preoperative MI ≥moderate and MI <moderate

Variable [mean ± SD or frequency (%)]	Preoperative MI ≥moderate (n = 28)	Preoperative MI <moderate (n = 58)	p value
Preoperative information			
Course of disease	60.1 ± 111.5	24.4 ± 35.3	0.091
Redo sternotomy	12 (42.9)	20 (34.5)	0.483
BMI	22.2 ± 3.7	24.1 ± 3.3	0.081
Loss of weight	4.9 ± 3.4	4.1 ± 2.9	0.230
Hypoproteinemia	16 (57.1)	25 (43.1)	0.255
NT-proBNP (pg/mL)	688.9 ± 780.8	409.1 ± 596.0	0.103
Renal dysfunction	2 (7.1)	3 (5.2)	0.659
Atrial arrhythmia	19 (67.9)	21 (36.2)	0.010
CTR	0.53 ± 0.06	0.52 ± 0.07	0.562
LAD	53.5 ± 13.7	46.4 ± 9.9	0.008
LVEDD	40.6 ± 6.1	40.7 ± 5.4	0.939
EF	60.0 ± 9.0	64.3 ± 8.4	0.035
Preoperative CVP (mmHg)	15.3 ± 5.6	14.9 ± 5.7	0.765
Operating time (min)	324.0 ± 118.3	237.7 ± 92.8	<0.001
Mitral intervention	17 (60.7)	13 (22.4)	<0.01
MVP	15 (53.6)	12 (20.7)	0.003
MVR	2 (7.1)	1 (1.7)	0.246
Postoperative information			
Postoperative CVP (mmHg)	6.2 ± 3.2	5.2 ± 2.4	0.118
Renal dysfunction	19 (67.9)	26 (45.6)	0.066
CRRT	4 (14.3)	0 (0)	0.010
New atrial fibrillation	4 (14.3)	0 (0)	0.010
Malignant arrhythmia	3 (10.7)	0 (0)	0.033
CTR	0.56 ± 0.06	0.54 ± 0.68	0.337
LA	45.6 ± 13.1	39.9 ± 8.9	0.024
LVEDD	42.3 ± 6.4	41.8 ± 4.4	0.716
EF	62.8 ± 9.0	64.9 ± 6.9	0.268
Tracheotomy	3 (14.3)	0 (0)	0.010
Re-intubation	4 (10.7)	0 (0)	0.033
ICU stay (days)	7.0 ± 11.3	2.3 ± 1.4	0.056
Hospital stay (days)	23.5 ± 13.6	17.3 ± 6.2	0.028
30-day mortality	3 (10.7)	2 (3.4)	0.324
Overall mortality	8 (26.6)	4 (6.9)	0.016

MI: mitral insufficiency; BMI: body mass index; BNP: brain natriuretic peptide; CTR: cardio-thoracic ratio; LAD: left atrial dimension; LVEDD: left ventricular end-diastolic dimension; EF: ejection fraction; CVP: central venous pressure; MVP: mitral valvuloplasty; MVR: mitral valve replacement; CRRT: continuous renal replacement therapy; ICU: intensive care unit

Partial pericardiectomy

Partial pericardiectomy (HR, 11.410; 95% CI [3.052–42.663]; p <0.001) was identified as an independent risk factor in the multivariate model, underscoring the need for pericardiectomy to be as complete as technically feasible. Moreover, we found that 32 (37.2%) patients were redo sternotomies because of previous partial pericardiectomy. Chowdhury and colleagues suggested that delayed improvement and persistent symptoms are most commonly the results of incomplete decortication.[7)] Therefore, partial pericardiectomy might be associated with increased mortality, decreased functional improvement, and the need for reoperation at follow-up. To remove the pericardium as completely as possible, the best approach should be selected. Although some studies have suggested that the left anterolateral approach permits greater access to the left ventricle, median sternotomy would allow enough access to the left ventricular

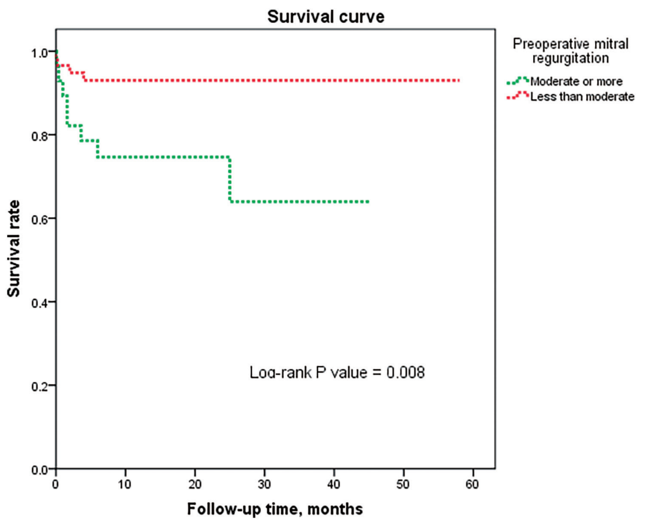

Fig. 2 Overall survival is significantly higher in patients with MI <moderate (red dotted line) compared with those with MI ≥moderate (green dotted line) (p = 0.008). MI: mitral insufficiency

pericardium by pulling the pericardium skillfully.[11,15] In addition, median sternotomy provides more radical clearance of the pericardium over the right atrium, venae cavae, and diaphragmatic surface, and allows extensive pericardial removal. Hence, most surgeons prefer to use this approach to the first and redo pericardiectomies. Nozohoor reported that radical pericardiectomy resulted in increased survival rates at 10 years (94%) compared to sub-total pericardiectomy (55%) (p = 0.014).[14] Radical pericardiectomy provided superior survival and clinical functional improvement in patients with chronic CP compared to sub-total pericardiectomy.

MI ≥moderate

Furthermore, the results of this study indicate the coexistence of significant mitral regurgitation and CP in one-fourth of patients coming to the surgery for pericardiectomy. The presence of significant mitral regurgitation is associated with increased overall mortality. Yangni-Angate et al. also argued that mitral regurgitation was an important risk factor; however, no specific reasons were analyzed.[24]

Mantri et al. reported that the postoperative outcome of mitral and tricuspid regurgitation revealed regression by at least 1 grade in 7 of the patients, and 7 persisted to have the same grade of regurgitation.[25] This is consistent with our findings; intraoperative TEE revealed an improvement in mitral regurgitation in 7 patients, while 4 patients continued to experience moderate or severe mitral regurgitation after pericardiectomy. Considering the pathophysiological changes after pericardiectomy, it is important to highlight that the removal of the pericardium can lead to the development of severe tricuspid regurgitation and, less frequently, mitral regurgitation. This occurrence is attributed to the acute dilation of the atrioventricular annuli following pericardiectomy.[2] Miranda et al. proposed that it should be taken into account when planning a pericardiectomy in patients with moderate atrioventricular regurgitation at baseline or when performing post-bypass intraoperative imaging following pericardial stripping.[2] The principle of simultaneous management of atrioventricular valves in pericardiectomy is the same as in our center. At our center, several patients after pericardiectomy were readmitted for surgical treatment owing to atrioventricular valve regurgitation. This subsequent procedure, following pericardiectomy, had a high risk and increased mortality rate. This is an important reason for our active treatment of atrioventricular valve regurgitation during pericardiectomy, even though it may improve in some patients after surgery. It should be noted that there have been several case reports on mitral valve insufficiency, with the majority suggesting that newly developed mitral valve insufficiency can gradually improve after pericardiectomy.[26–29] However, there are few reports on the prognosis of patients with preoperative mitral regurgitation. Further clarifications of the specific mechanism and prognosis require extensive studies with a large number of cases.

Limitation

Although we ensured scientific rigor in conducting this study, a few limitations exist. First, this was a retrospective study, and as such, it is subject to the limitations inherent in retrospective analysis. Moreover, no Swan-Ganz cauterization pressure data were assessed in all patients. Thus, we could not include all univariate significant variables with many missing values in the multiple models. Third, the sample size was relatively small; hence, the results should be interpreted cautiously. Larger sample studies with longer follow-up durations are needed in the future.

Conclusions

Pericardiectomy continues to be a safe operation for CP with optimal mid-term outcomes. Preoperative MI ≥moderate and partial pericardiectomy are significant risk factors for decreased mid-term survival. Although valve repair has little impact on late survival, MI seldom improves with pericardiectomy alone. Nevertheless, it may be considered to reduce symptoms, as it can be undertaken without increasing operative risk.

Declarations

Ethics approval and consent to participate

The study was approved by the Institutional Review Board of Peking University International Hospital (protocol code 2021-008 [BMR]), and patient consent was waived at Peking University International Hospital.

Consent for publication

All authors have read and agreed to the published version of the manuscript.

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Data availability

The original contributions presented in the study are included in the article, and further inquiries can be directed to the corresponding author.

Author contributions

Bin Li and Shen Liu: conception and design. Chao Dong and Jianping Xu: provision of study materials or patients. Bin Li, Ruofan Liu, Minghui Tong, and Shen Liu: data management and statistical analysis. Bin Li: manuscript writing. Bin Li, Shen Liu, and Guangyu Pan: manuscript editing. Guangyu Pan, Shen Liu, and Jianping Xu: supervision or mentorship.

Disclosure statement

The authors declare no conflict of interest.

Supporting Information

Supplementary video

Off-pump pericardiectomy.

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