



Clinical and echocardiographic outcomes of patients with mitral annular calcification undergoing mitral valve surgery: a 10-year single center experience

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Background: Mitral annular calcification (MAC) is a chronic and degenerative process, affecting the mitral valve annulus. MAC complicates the decision over the appropriate surgical approach to mitral valve disease. Distorted valvular anatomy increases surgical risk and therefore requires careful patient selection. Here, we report our single-center experience performing mitral valve surgery in the setting of MAC over a 10-year period.

Methods: This is a 10-year retrospective analysis of 172 patients with MAC. Sixty-seven patients underwent MAC severity scoring using a 10-point system based on computed tomography (CT). The primary outcome was 30-day mortality, readmission, reoperation, stroke, prolonged ventilation, renal failure and deep sternal infection. Secondary analyses stratified MAC by underlying mitral disease type as well as evaluated outcomes by CT severity score. Patients without MAC undergoing mitral valve replacement surgery during the same time period served as controls.

Results: The 30-day mortality was significantly higher in MAC patients compared with non-MAC (9.9% *vs.* 4.2%, $P < 0.001$), as were rates of stroke (4.7% *vs.* 1.6%, $P = 0.036$), prolonged ventilation (33.1% *vs.* 21.1%, $P < 0.001$), and renal failure (8.7% *vs.* 4.3%, $P = 0.008$). Resource utilization was also greater, with longer intensive care unit (ICU) hours [118 [interquartile range (IQR), 58.2–254] *vs.* 72.3 (IQR, 41.0–141.5) hours, $P < 0.001$], postoperative length of stay [10 (IQR, 7–22) *vs.* 8 (IQR, 6–13) days, $P < 0.001$], and total hospitalization [12 (IQR, 8–28) *vs.* 10 (IQR, 6–17) days, $P = 0.001$].

Conclusions: MAC complicates mitral valve surgery, with significant differences seen in survival stroke, renal failure, prolonged ventilatory support, and ICU and hospital length of stay. Careful evaluation of surgical risk and patient selection is warranted in patients with MAC.

Keywords: Mitral annular calcification (MAC); mitral valve; echocardiographic outcomes



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Introduction

Mitral annular calcification (MAC) is a chronic and degenerative condition characterized by a progressive deposition of calcium along the fibrous base of the mitral valve annulus (1). The prevalence of MAC increases with age and is higher in populations with chronic kidney disease and severe atherosclerosis (2). MAC forms because of a complex interplay between the inflammatory pathways, oxidative injury and disruptions in calcium-phosphate homeostasis (3). Additionally, MAC has been independently associated with adverse cardiac outcomes such as atrial fibrillation, myocardial infarction, stroke and increased mortality (3). MAC is present in approximately 8–15% (4,5) of patients with mitral valve disease, most commonly affecting elderly individuals, women, and those with coronary artery disease, a history of chest radiation, or prior aortic valve replacement. The prevalence is also higher in patients with chronic kidney disease and advanced atherosclerosis (5).

MAC is typically detected incidentally on echocardiography or computed tomography (CT) and can mimic a vegetation or intracardiac mass (6,7). It can range from focal, non-obstructive lesions to severe, circumferential lesions that significantly distort annular geometry and impede valve function (4). MAC severity is classified using a combination of echocardiography and multidetector CT (MDCT). These modalities evaluate average calcium thickness (mm), degrees of annulus circumference involved, calcification at one or both fibrous trigones, and calcification of one or both leaflets. A MAC score of greater than 7, for example, is often used to define severe MAC (2). Classification and grading of MAC is key to preprocedural planning of surgical and transcatheter interventions as it allows for assessment of annular suitability for valve anchoring and stratifies risk for complications like embolization and paravalvular leak.

Management of mitral valve disease in the setting of severe MAC remains a formidable surgical challenge. Traditional surgical mitral valve replacement (MVR) is technically demanding due to a high risk of annular disruption, atrioventricular (AV) groove rupture, improper seating of the prosthetic valve and coronary artery injury (5). Despite the advent of various more sophisticated surgical techniques and hybrid transcatheter approaches to address MAC, the traditional surgical approach with sternotomy and direct visualization of the mitral valve remains the most common (6,8). The operation is complex and usually involves an extensive calcium debulking of the mitral

annulus, usually achieved using surgical debridement, *en-bloc* resection of the affected segments followed by patch reconstruction (5,9). This technique carries an increased risk of catastrophic complications, with a mortality rate up to 9–10% (10). Due to the complexity, surgery is typically reserved for patients with favorable anatomy and acceptable operative risk and is typically performed in high-volume centers with specialized expertise. Nonetheless, newer techniques employing focused ultrasound to fragment and debride the calcified annulus are being explored, with the goal of preserving leaflet integrity and mobility, minimizing the risk of AV groove disruption, and facilitating annular remodeling (11,12).

Here, we describe our 10-year single center experience with MAC patients that underwent surgical intervention. The results will help educate and inform surgical teams about the clinical profile of MAC patients as well as help establish pre-operative parameters that may increase post-operative morbidity and mortality.

Methods

Patients

Review of the institutional data between July 2015 to May 2025 yielded 2,489 patients that underwent mitral valve surgery, of which 273 patients had documented MAC. The medical records, operative notes and preoperative imaging of the 273 patients were reviewed after which 172 were confirmed to have MAC by intra-operative findings noted by the primary surgeon. Sixty-seven of these patients had preoperative CT imaging that allowed for MAC severity scoring. Demographic, clinical, echocardiographic, and peri-operative characteristics of the mitral valve surgery cohort and MAC patients were collected. The location, disease type, and severity of the MAC disease were analyzed.

Operative approach

All operations were performed using standard cardiopulmonary bypass via a median sternotomy. After aortic cross-clamping and cardioplegic arrest, the mitral valve was exposed through a left atriotomy in Waterston's groove. The valve and annulus were systematically inspected to define the extent and distribution of MAC, leaflet involvement, and subvalvular disease. In patients with extensive MAC, a conventional surgical MVR strategy or an open transatrial valve-in-MAC approach was selected at the discretion of

the operating surgeon based on intraoperative anatomy and perceived risk of annular disruption.

In cases managed with conventional surgical replacement, bulky calcium along the posterior annulus was carefully cored out and thinned using rongeurs and sharp curettes, with selective use of ultrasonic or high-speed debridement devices when needed. Resection was generally segmental rather than circumferential, aiming to remove obstructive or unstable calcific plaques while preserving the fibrous skeleton and avoiding AV groove disruption or circumflex coronary injury. Residual annular defects after decalcification were reconstructed with bovine or autologous pericardial patches to restore a smooth neo-annulus suitable for prosthetic valve seating. Pledgeted, interrupted sutures were then placed either in preserved fibrous annulus, reconstructed patch, or a narrow rim of residual leaflet tissue, with the pledgets kept on the atrial side to distribute tension and reduce the risk of paravalvular leak.

In patients with severe, circumferential MAC in whom extensive annular decalcification was judged high risk, an open transatrial valve-in-MAC technique with a balloon-expandable transcatheter heart valve was employed. After left atrial exposure, the anterior leaflet was systematically resected, leaving a narrow rim of tissue to facilitate suture anchoring and to mitigate the risk of left ventricular outflow tract obstruction. Multiple pledgeted sutures were placed equidistantly around the calcified annulus into residual leaflet tissue or limited debrided segments. A 0.75–1.0 cm felt strip was sewn to the inflow portion of the transcatheter valve frame to create a sealing skirt, and the valve was deployed under direct vision. The pledgeted sutures were then tied to the felt skirt and frame to secure the prosthesis and enhance sealing.

CT scoring analysis

MAC severity scoring using preoperative, gated CT imaging was performed on 67 of the 172 MAC patients. Ninety-two patients did not have a CT, while 13 patients had poor quality imaging preventing accurate scoring. Average annular calcium thickness, calcium distribution in the annular circumference, trigone calcification and leaflet calcification were evaluated and given a score out of 10. Calcium thickness less than 5 mm with less than 180-degree annular involvement received a score of 2, while calcium thickness greater than 10 mm with greater than 270-degree annular involvement, complete trigonal and

leaflet calcification received a score of 9. MAC score of less than 3 was considered mild, 4–6 considered moderate and 7 or greater considered severe (2) (*Figure 1*).

Statistical analysis

Demographic and clinical characteristics were summarized for all MAC patients. Frequencies were reported for categorical variables. Continuous variables were evaluated for normality using the Shapiro-Wilk test. Normally distributed variables were reported as mean and standard deviation (SD), and non-normally distributed variables were summarized as median and interquartile range (IQR). Frequencies of operative outcomes were also summarized in the same fashion and compared between CT-MAC and non-MAC patients. Mann-Whitney *U* tests and Chi-squared tests were used to evaluate the differences for continuous and categorical variables, accordingly.

Outcomes were defined according to Society of Thoracic Surgeons (STS) standards. Operative mortality was defined as all-cause death during the index hospitalization (regardless of duration, including inter-hospital transfers) or within 30 days of surgery. Deep sternal infection required evidence of mediastinitis within 30 days postoperatively. Reoperation included any unplanned return to the operating room for cardiac indications. Stroke was defined as a new focal neurological deficit of abrupt onset persisting for more than 24 hours. Prolonged ventilation was defined as mechanical ventilation exceeding 24 hours postoperatively, including total hours across all intubations. Renal failure was included as a major morbidity endpoint per STS definitions. 30-day readmission was defined as rehospitalization to an acute-care facility within 30 days of discharge. Intensive care unit (ICU) stay was calculated as the total number of hours at ICU level of care, including both initial and any subsequent ICU admissions, and hospital length of stay was measured as the total number of postoperative days. Combined morbidity and mortality were defined as having any of the primary outcomes, excluding readmission.

Patients' outcomes were also compared according to underlying mitral disease type [mitral regurgitation (MR), mitral stenosis (MS), and mixed]. Chi-squared tests were used to assess whether significant differences existed in categorical outcomes across these groups. The characteristics of MAC, including its location, type, and severity, were described along with the distribution of mitral disease. For patients with available echocardiographic

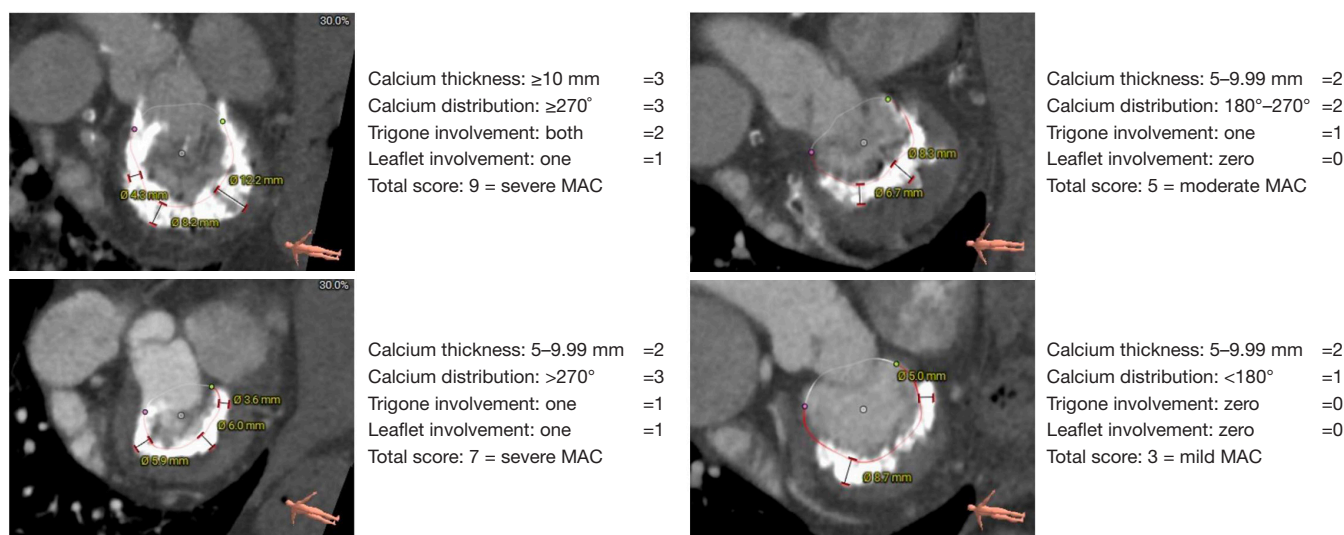


Figure 1 MAC CT images with scoring examples. CT, computed tomography; MAC, mitral annular calcification.

data, pre- and postoperative mean and peak gradients were reported. For baseline, outcome and echocardiographic variables with missing data, the number of patients with available information is reported, and percentages are calculated using the non-missing denominator for that variable. Patients with missing data (Tables S1-S3) for a given variable were excluded from percentage calculations but retained in the overall cohort.

Multivariable logistic regression models adjusting for age, sex, diabetes, hypertension, and prior cardiac interventions were constructed to evaluate the association between CT-derived MAC severity scores and selected operative outcomes (results provided in Table S4). A two-sided P value <0.05 was considered statistically significant. All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

Demographics and preoperative characteristics of MAC and non-MAC patients

MAC patients were predominantly female (61.6%) with a mean age of 73 (IQR, 65–78) years old. Comorbidities included hypertension (83.7%), diabetes (36.6%), chronic lung diseases (43%) and a history of smoking (44.9%). At the time of surgery, more than half had already undergone some type of cardiac procedure including valvular surgery (22.1%), percutaneous coronary intervention (PCI) (19.2%)

or coronary artery bypass grafting (9.9%). Patients were also complicated by a history of heart failure (83.4%), cerebrovascular disease (26.7%), myocardial infarction (9.3%) and infective endocarditis (7.6%). Three-point-five percent of patients deteriorated into cardiogenic shock prior to surgery and 37.8% required urgent or emergent surgery due to valve dysfunction (55.6%), congestive heart failure (17.5%) and endocarditis (9.5%). Pre-operative ejection fraction (EF) and creatinine level were 63% (IQR, 55–68%) and 1.05 (IQR, 0.84–1.44) mg/dL, respectively (Table 1). Full median sternotomy was favored in the majority of cases, with only five cases of mini thoracotomy or percutaneous approach. Forty-seven patients required concomitant CABG and 4 needed concomitant aortic valve replacement. Cardiopulmonary bypass time averaged 180 (IQR, 127–213; SD, 72) minutes, and aortic clamp cross clamp time was 131 (IQR, 91–161; SD, 54) minutes on average (Table S5).

Non-MAC patients were predominantly male (54.3%) with a median age of 66 (IQR, 57–74) years. The most common comorbidities included hypertension (65.9%), diabetes (18.0%), and chronic lung disease (25.7%), while just over one-third had a history of smoking (38.3%). A substantial proportion had prior cardiac procedures, most commonly previous valve intervention (24.2%), PCI (8.7%), and CABG (5.6%). Pre-operative characteristics included a high prevalence of heart failure (71.4%), cerebrovascular disease (16.9%), myocardial infarction (8.1%), and infective

Table 1 MAC and non-MAC demographic and clinical characteristics			
Variables	MAC (n=172)	Non-MAC (n=2,209)	P value
Age (years)	73 [65, 78]	66 [57, 74]	<0.001
Gender			<0.001
Male	66 (38.4)	1,199 (54.3)	
Female	106 (61.6)	1,010 (45.7)	
Smoking history			0.039
Never	93 (55.0)	1,323 (62.0)	
Current	9 (5.3)	165 (7.7)	
Past smoker	67 (39.6)	655 (30.6)	
Diabetes	63 (36.6)	397 (18.0)	<0.001
Hypertension	144 (83.7)	1,454 (65.9)	<0.001
Liver disease	5 (2.9)	43 (1.9)	0.389
Dialysis	18 (10.5)	77 (3.5)	<0.001
Immunosuppressed	17 (9.9)	114 (5.2)	0.009
Chronic lung disease			<0.001
None	96 (57.1)	1,610 (74.3)	
Mild	37 (22.0)	335 (15.5)	
Moderate/severe	35 (20.8)	222 (10.2)	
Peripheral vascular disease	8 (4.7)	94 (4.3)	0.805
Cerebrovascular disease	46 (26.7)	373 (16.9)	0.001
Cerebrovascular accident	25 (14.5)	242 (11.0)	0.154
Previous myocardial infarction	16 (9.3)	178 (8.1)	0.571
Previous cardiac intervention	84 (50.2)	914 (41.4)	0.027
Previous CABG	17 (9.9)	123 (5.6)	0.021
Previous valve intervention	38 (22.1)	534 (24.2)	0.538
Previous PCI	33 (19.2)	192 (8.7)	<0.001
Mediastinal radiation	9 (5.2)	34 (1.5)	<0.001
Endocarditis	13 (7.6)	320 (14.5)	0.012
Active	8 (4.7)	197 (8.9)	0.055
Treated	5 (2.9)	123 (5.6)	0.136
Preoperative EF (%)	63 [55, 67.9]	58 [52.5, 63]	<0.001
Preoperative creatinine (mg/dL)	1.05 [0.8, 1.4]	1.0 [0.81, 1]	0.007
Preoperative hematocrit ($\times 10^3/\mu\text{L}$)	36.0 \pm 6	38.15 \pm 6	<0.001
Preoperative white blood cell count ($\times 10^3/\mu\text{L}$)	7.2 [6.1, 8.7]	6.92 [5.7, 8.3]	0.073
Preoperative hemoglobin (g/dL)	11.6 \pm 2.1	12.5 \pm 2.3	<0.001

Table 1 (continued)

Table 1 (continued)

Variables	MAC (n=172)	Non-MAC (n=2,209)	P value
Platelets (μL)	224,000 [183,500, 273,500]	205,000 [167,000, 253,000]	0.007
Cardiogenic shock	6 (3.5)	77 (3.5)	>0.99
Heart failure	141 (83.4)	1,561 (71.4)	<0.001
Surgery status			0.233
Elective	107 (62.2)	1,392 (63.0)	
Emergent	58 (33.7)	772 (34.9)	
Urgent	7 (4.1)	41 (1.9)	

Data are presented as median [interquartile range], mean \pm standard deviation or n (%). CABG, coronary artery bypass graft; EF, ejection fraction; MAC, mitral annular calcification; PCI, percutaneous coronary intervention.

Table 2 Primary outcomes in MAC and non-MAC cohorts

Primary outcome	MAC (n=172)	Non-MAC (n=2,209)	P value
Death	17 (9.9)	92 (4.2)	<0.001
Deep sternal infection	1 (0.6)	9 (0.4)	0.729
Reoperation	21 (12.2)	203 (9.2)	0.192
Stroke	8 (4.7)	35 (1.6)	0.036
Prolonged ventilation	57 (33.1)	466 (21.1)	<0.001
Renal failure	15 (8.7)	95 (4.3)	0.008
Readmission	19 (13.0)	203 (9.8)	0.219
Combined morbidity and mortality	67 (39.0)	573 (25.9)	<0.001

Data are presented as n (%). MAC, mitral annular calcification.

endocarditis (14.5%), with 5.6% presenting with active infection. At the time of surgery, 3.5% were in cardiogenic shock, and 36.8% required emergent or urgent intervention. Median EF was 58% (IQR, 52.5–63%), and creatinine was 1.0 (IQR, 0.81–1.23) mg/dL (Table 1).

Primary outcomes: MAC vs. non-MAC patients

Among patients with MAC, operative mortality was significantly higher compared with non-MAC patients (9.9% vs. 4.2%, $P<0.001$). The incidence of stroke was also greater in the MAC cohort (4.7% vs. 1.6%, $P=0.036$), as were rates of prolonged ventilation (33.1% vs. 21.1%, $P<0.001$) and postoperative renal failure (8.7% vs. 4.3%, $P=0.008$). Overall major morbidity, defined as the composite endpoint of mortality, stroke, reoperation, renal failure,

deep sternal infection and readmission, was more frequent in MAC patients (39.0% vs. 25.9%, $P<0.001$). In contrast, rates of deep sternal wound infection (0.6% vs. 0.4%, $P=0.729$), reoperation (12.2% vs. 9.2%, $P=0.192$), and 30-day readmission (13.0% vs. 9.8%, $P=0.219$) did not differ significantly between groups (Table 2).

Secondary outcomes: MAC vs. non-MAC patients

Total ICU hours were markedly longer in the MAC group, with a median of 118 (IQR, 58.2–254) hours compared with 72.3 (IQR, 41.0–141.5) hours in non-MAC patients ($P<0.001$). Similarly, total ICU length of stay was prolonged in MAC patients at 4.9 (IQR, 2.4–10.5) versus 3.0 (IQR, 1.7–5.9) days in the non-MAC group ($P<0.001$). Postoperative length of stay from surgery to discharge

Table 3 Secondary outcomes in MAC and non-MAC cohorts

Secondary outcome	MAC (n=172)	Non-MAC (n=2,209)	P value
Total ICU days	5 [2, 11]	3 [2, 6]	<0.001
Length of stay days (surgery to discharge)	10 [7, 22]	8 [6, 13]	<0.001
Length of stay days (admission to discharge)	12 [8, 28]	10 [6, 17]	<0.001

Data are presented as median [interquartile range]. ICU, intensive care unit; MAC, mitral annular calcification.

Table 4 Primary outcomes in MAC cohort when stratified by disease type

Primary outcome	MR (n=55)	MS (n=34)	Mixed (n=53)	P value
Death	5 (9.1)	6 (17.6)	4 (7.5)	0.297
Deep sternal infection	1 (1.8)	0	0	0.462
Reoperation	6 (10.9)	6 (17.6)	6 (11.3)	0.608
Stroke	2 (3.6)	3 (8.8)	0	0.095
Prolonged ventilation	21 (38.2)	11 (32.4)	19 (35.8)	0.857
Renal failure	2 (3.6)	4 (11.8)	5 (9.4)	0.323
Readmission	5 (10.4)	4 (14.3)	5 (11.9)	0.882
Combined morbidity and mortality	22 (40.0)	16 (47.1)	20 (37.7)	0.682

Data are presented as n (%). MAC, mitral annular calcification; MR, mitral regurgitation; MS, mitral stenosis.

was also significantly longer in MAC patients, 10 (IQR, 7–22) days compared with 8 (IQR, 6–13) days in non-MAC patients ($P<0.001$). Finally, total hospitalization from admission to discharge was extended in the MAC cohort, 12 (IQR, 8–28) days compared with 10 (IQR, 6–17) days in non-MAC patients ($P<0.001$) (Table 3).

MAC characteristics and echocardiographic outcomes

Within the MAC cohort of 172 patients, circumferential annular calcification was the most common (55.3%) intraoperative finding, followed by posterior (35.3%) and anterior (9.4%) involvement. By echocardiography, 38.7% of patients had MR, 23.9% MS, and 37.3% mixed disease (Table 4). MR severity was distributed as mild (25.5%), moderate (34.0%), and severe (28.4%), while MS severity was predominantly severe (57.5%). Postoperatively, mean and peak gradients of the entire cohort decreased from 8 (IQR, 6–12) and 20 (IQR, 14–26) mmHg to 5 (IQR, 4–6) and 13 (IQR, 10–15) mmHg, respectively. Residual MR was less than mild in over 90% of patients, and greater than mild paravalvular leak occurred in only 4% (Table 5).

CT imaged subgroup analysis

Based on MAC severity scoring, 14 patients had mild MAC, 25 had moderate MAC and 28 had severe MAC (Table S4). Mean severity score was 5.7 with an SD of 2.27. When MAC severity score was modeled as a continuous variable, there were no statistically significant associations with primary outcomes. Odds ratios (ORs) suggested possible trends toward increased risk of death [OR 1.5, 95% confidence interval (CI): 0.9–2.6, $P=0.128$], reoperation (OR 1.3, $P=0.344$), prolonged ventilation (OR 1.2, $P=0.212$), renal failure (OR 1.2, $P=0.436$), and 30-day readmission (OR 1.1, $P=0.646$), but none reached statistical significance (Table S6).

Mortality occurred in 8.9% of patients. Major complications included prolonged ventilation in 26.9%, reoperation in 10.5%, renal failure in 8.7%, and stroke in 4.6%. Deep sternal infection was rare (1.5%). Thirty-day readmission occurred in 10.9% (Table S7). The median initial ICU stay was 120 (IQR, 58–189) hours, with total ICU duration of 127 (IQR, 58–214) hours. Median total ICU stay was 9.6 (IQR, 2.4–8.9) days. Median postoperative

Table 5 Echocardiographic findings of MAC and CT-MAC cohorts

Variable	MAC (n=172)	CT-MAC (n=67)
MAC severity by visual inspection		
Mild	2 (1.1)	0
Moderate	13 (7.6)	1 (1.5)
Severe	157 (91.3)	64 (98.5)
MAC location		
Anterior	16 (9.4)	4 (6.2)
Circumferential	94 (55.3)	45 (69.2)
Posterior	60 (35.3)	16 (24.6)
MV disease		
MR	55 (38.7)	15 (23.8)
MS	34 (23.9)	24 (38.1)
Mixed	53 (37.3)	24 (38.1)
MS severity		
Mild	4 (4.2)	1 (2.0)
Moderate	30 (31.9)	19 (37.3)
None	6 (6.4)	2 (3.9)
Severe	54 (57.5)	29 (56.9)
MR severity		
None	4 (2.8)	1 (1.6)
Trace	13 (9.2)	9 (14.5)
Mild	36 (25.5)	17 (27.4)
Moderate	48 (34.1)	22 (35.5)
Severe	40 (28.4)	13 (21.0)
Preoperative mean gradient (mmHg)	8 [5.6, 12]	8 [5.6, 13.5]
Preoperative peak gradient (mmHg)	19.5 [14, 26.3]	20 [15, 30]
MV area (cm ²)	1.4 [1.1, 1.8]	1.45 [1.1, 1.8]
Postoperative mean gradient (mmHg)	5 [3.7, 6]	4.8 [3.85, 6.1]
Postoperative peak gradient (mmHg)	13 [10.1, 15]	14 [10.1, 16]
Central MR		
None	76 (56.3)	39 (62.0)
Trace	48 (35.6)	21 (33.3)
Mild	10 (7.4)	2 (3.2)
Moderate	1 (0.7)	1 (1.6)

Table 5 (continued)**Table 5** (continued)

Variable	MAC (n=172)	CT-MAC (n=67)
Postoperative PVL		
None	107 (84.9)	3 (4.8)
Trace	8 (6.4)	2 (3.2)
Mild	7 (5.6)	54 (85.7)
Moderate	3 (2.4)	1 (1.6)
Severe	1 (0.7)	3 (4.8)

Data are presented as median [interquartile range] or n (%). CT, computed tomography; MAC, mitral annular calcification; MR, mitral regurgitation; MS, mitral stenosis; MV, mitral valve; PVL, paravalvular leak.

length of stay was 10 (IQR, 7–22) days, and total hospital stay from admission to discharge was 14 (IQR, 9–27) days (Table S8). Death (8.9% vs. 9.9%), reoperation (10.5% vs. 12.2%), stroke (4.6% vs. 6.3%), prolonged ventilation (26.9% vs. 33.1%) and readmission rates (10.9% vs. 13%) were lower in the CT MAC group when compared to the overall cohort.

Discussion

This single center 10-year retrospective analysis characterizes a high-risk cohort undergoing mitral valve surgery in the setting of extensive MAC. Our primary study results were: (I) MAC increased operative mortality two-fold when compared to non-MAC mitral valve patients; (II) MAC was associated with a statistically significant increase in stroke, renal failure and prolonged ventilation compared to non-MAC mitral valve patients; (III) MAC patients experienced longer ICU and hospital length of stay compared to non-MAC mitral patients; (IV) surgical treatment of MAC produced favorable hemodynamic outcomes as seen by echocardiography; (V) underlying mitral disease pathology did not statistically affect primary or secondary outcomes in MAC patients; (VI) the use of CT based severity scoring may decrease the risk of post operative morbidity and mortality although further investigation is warranted.

Our MAC-cohort of patients showed representative characteristics of patients reported in the literature with MAC-complicated MVD (10,12), which reinforces the possible correlation between specific comorbidities and calcification of the mitral valve. Whether synergic or singular, their respective effects on the pathophysiology

of MAC and subsequent surgical outcomes are notable and warrant further investigation. Nonetheless, their significance in determining the overall approach to MAC cannot be overstated as it may signal a shift in the treatment paradigm.

It is well documented that MAC is associated with an increased risk of cardiovascular and all-cause mortality. Compared to non-MAC patients, this cohort displays a similar trend in worse 30-day outcomes and prolonged hospital length of stay. Although the mechanics of this relationship are complex, the interplay between an extremely comorbid profile and high-risk surgery suggests a causal relationship. The conventional surgical approach singularly carries a high burden of cardiovascular risk, including stroke, renal failure and death, as observed in our analysis. The use of novel ultrasonic waves to debride the calcific annulus is believed to lower the rate of post-surgical stroke (11) and may be critical in treating MAC patients in the future.

Although mitral valve surgery in the setting of MAC is technically challenging, our study demonstrated favorable hemodynamic outcomes with improved postoperative gradients and minimal residual MR or paravalvular leak. Importantly, the comparable rate of reintervention between MAC and non-MAC patients suggests that patient selection and preoperative characteristics may play a more significant role in determining outcomes than surgical technique alone.

Our stratification of MVD by type was not a statistically significant predictor of primary outcomes. However, it is worth noting that while MAC was mostly associated with MR in our cohort, MAC-associated MS patients tended to have worse 30-day post-surgical outcomes. While not of statistical significance, it may be of clinical importance, and such findings advocate for a comprehensive evaluation of patients with a favorable clinical profile and mitral valve pathology to absorb inherent risks.

MAC requires a multi-modality imaging approach. Transthoracic echocardiography (TTE) is usually first line and provides significant details on the valve anatomy. However, its poor sensitivity makes transesophageal echocardiography (TEE) and MDCT preferable for better characterization of MAC. From our MAC-cohort of 273 patients, only 172 (63%) were confirmed to have MAC by visual confirmation. This alludes to the ambiguity of distinguishing calcification from fibrosis. Of the 172 patients with confirmed MAC, only 103 (59%) had an MDCT, with 67 (39%) of them allowing for accurate severity scoring.

Primary outcomes were marginally improved in the CT-MAC cohort. The dynamics of such improvement may be reflective of better pre-operative planning. Moreover, it offers a glimpse of a possible paradigm shift in management of MAC patients where a system that combines patient's comorbidities and detailed MAC imaging characterization may optimize patient's outcomes from a highly complex surgical procedure.

The study has several limitations including a small MAC and CT-MAC cohort making it difficult to draw definitive conclusions, however it does provide early insight into the elevated risk and importance of a multidisciplinary approach in treating patients with MAC. Additionally, there was a significant amount of missing echocardiographic data limiting our ability to draw definitive conclusions on gradient changes. Future studies should focus on risk stratification models specific to MAC patients and how severity assessment methods might improve outcomes. As the population of patients with prior bioprosthetic valves and MAC continues to grow, understanding the nuances of each patient risk profile will help drive decision making that provides the most beneficial outcome to the patient.

Conclusions

MAC remains a formidable challenge in mitral valve surgery, conferring significantly higher operative morbidity and mortality compared with non-MAC patients. We show that MAC was associated with increased rates of stroke, renal failure, ventilation time and prolonged ICU and hospital stays. Despite this elevated risk profile, postoperative hemodynamic results were favorable. Disease subtype did not significantly influence outcomes, underscoring the dominant impact of annular calcification itself. CT-based MAC severity scoring demonstrated potential utility in refining preoperative planning, although larger studies are needed to validate its prognostic value. These findings highlight the importance of meticulous patient selection and multidisciplinary evaluation in managing MAC patients. As the prevalence of MAC continues to rise, improved imaging strategies, evolving surgical techniques, and risk-stratification tools will be essential to optimize outcomes in this high-risk population.

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Footnote

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