Featured Article

Ultrasonic emulsification to facilitate mitral valve reconstruction in mitral annular calcification

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Background: Mitral annular calcification (MAC) increases the complexity and risk of mitral valve surgery, often limiting repair feasibility. This study evaluates the early outcomes of ultrasonic emulsification and aspiration using a novel device to facilitate mitral valve repair.

Methods: We conducted a prospective, single-centre, single-surgeon series of 27 consecutive patients with moderate-to-severe MAC and degenerative mitral regurgitation (MR) undergoing Sonopet-assisted decalcification between June 2023 and July 2025. Procedures were performed via median sternotomy or endoscopic mini-thoracotomy. Ultrasonic aspiration was used to remove and sculpt MAC, enabling annular remodelling and secure repair. The primary outcome was repair success and residual regurgitation; secondary outcomes included mortality and perioperative complications.

Results: Mitral repair was successfully performed in 26 patients (96.3%), with one conversion to replacement. There were no in-hospital deaths, strokes, atrioventricular (AV) groove disruptions, or reoperations. At discharge, 96.3% had none or mild residual MR; one patient (3.7%) had moderate MR. Mean coaptation length was 10.3±3.2 mm. Postoperative complications included new-onset atrial fibrillation in five patients (18.5%) and permanent pacemaker implantation in two (7.4%). Sternotomy approach was used in 63% and endoscopic mini-thoracotomy in 37%. Mean cardiopulmonary bypass (CPB) and cross-clamp times were 159.6±46.8 and 116.9±46.5 min, respectively. Most mitral repairs addressed isolated posterior leaflet prolapse (66.7%) or bileaflet prolapse (22.2%). Primary repair strategies included leaflet resection (51.9%), isolated neochords (25.9%), or resection with neochords (22.2%). MAC decalcification was primarily performed in the posterior annulus.

Conclusions: Ultrasonic emulsification is a safe, effective adjunct for mitral valve repair in moderate-to-severe MAC, enabling precise decalcification and high repair rates with minimal complications. This approach may expand repair candidacy and merits further comparative studies with long-term follow-up.

Keywords: Mitral annular calcification (MAC); ultrasonic emulsification; mitral valve repair

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Introduction

Mitral annular calcification (MAC) is a chronic, degenerative condition marked by progressive calcium deposition in the mitral annulus, impairing its function (1,2). Moderate or severe mitral regurgitation (MR) may occur in up to 30% of patients with MAC, while mitral stenosis is less common (3). The combination of MAC and mitral valve pathology poses surgical challenges, with lower repair rates, higher perioperative morbidity, and increased mortality in the range of 6–14% (1,2,4,5). It predisposes to complications such as paravalvular leak, circumflex artery injury, calcific embolization, stroke, and most critically, atrioventricular (AV) groove disruption—a particularly feared complication (2,6,7). Mild, localized MAC affecting less than one-third of the annular circumference usually does not impede surgical repair or replacement, but moderate to severe MAC

requires careful preoperative planning (5).

Surgical approaches to MAC include complete *en bloc* resection, partial debridement, annular patch reconstruction, and, increasingly, transcatheter mitral valve replacement (TMVR). Strategy selection depends on factors such as age, comorbidities, MAC severity and distribution, and surgical expertise (1,2,8,9). When feasible, mitral valve repair is preferred over replacement, offering superior early and late outcomes, including better preservation of left ventricular function, fewer complications, and improved long-term survival (5,10-12). However, repair-to-replacement conversion rates are higher in MAC patients *vs.* those without it (8% *vs.* 3%) (5,7,13). Previously, we had commonly used traditional techniques of MAC debridement with sharp dissection and *en-bloc* or piecemeal resection when feasible. We had learned about ultrasonic emulsification using the Sonopet Ultrasonic Aspirator® (Stryker, Kalamazoo, MI, USA) from our Japanese colleagues and a case series from Michigan for enabling mitral valve replacement (14,15). In this report, we describe the feasibility and early outcomes of using the Sonopet Ultrasonic Aspirator® (Stryker) in 27 patients with moderate-to-severe MAC undergoing mitral valve surgery to facilitate mitral valve repair.

Methods

Intervention and study design

This study was approved by the local research ethics board, which waived the need for individual patient consent. All mitral valve operations utilizing Sonopet-assisted decalcification were performed by a single surgeon (M.W.A.C.) between June 2023 and July 2025 at London Health Sciences Centre (London, ON, Canada). Patients were planned for mitral valve repair as the primary intervention for degenerative MR in the presence of at least moderate MAC, confirmed by echocardiography and/or computed tomography. Exclusion criteria included secondary MR, initial mitral valve replacement strategy, or use of non-Sonopet decalcification techniques.

Prospectively collected data included demographics, clinical and imaging characteristics, intraoperative variables, and postoperative in-hospital outcomes. Intraoperative three-dimensional transesophageal echocardiography (TEE) was used to obtain post-repair measurements under physiologic loading conditions, including coaptation length, which was measured at mid-systole in the mid-esophageal long-axis view (0° or 120°, based on image quality and valve orientation) in accordance with American Society of Echocardiography guidelines (16). All patients underwent transthoracic echocardiography prior to discharge.

Outcomes and endpoints

The primary outcome was mitral repair success. Secondary outcomes included in-hospital mortality, reintervention for mitral valve dysfunction or bleeding, AV groove disruption, respiratory failure (≥48 hours ventilated), wound infection, acute renal failure (requiring dialysis), myocardial infarction, stroke, new-onset atrial fibrillation, permanent pacemaker implantation, and post-repair residual MR. Additional operative variables included cardiopulmonary bypass (CPB) time, aortic cross-clamp time, and coaptation length.

Statistical analysis

All statistical analyses were performed using the most recent version of R (version 4.5.1; R Foundation for Statistical Computing, Vienna, Austria) (R Core). Categorical variables were summarized as counts and percentages, while continuous variables were reported as means with standard deviations (SDs). Data completeness and distributions were assessed prior to analysis with <10% missingness for any variable or observation.

Calcific emulsification operative techniques

Ultrasonic emulsification of MAC was performed using the Sonopet Ultrasonic Aspirator® (Stryker) in a cohort of 27 consecutive patients undergoing mitral valve surgery via either median sternotomy or right anterolateral mini thoracotomy. The decision to employ the Sonopet was based on preoperative imaging indicating moderate-to-severe MAC, in conjunction with intraoperative assessment of annular calcification extent and location.

The Sonopet device uses high-frequency ultrasonic energy delivered through the device tip to directly emulsify calcium while simultaneously aspirating to minimize the risk of embolization (*Figure 1*, *Video 1*). The instructions for use suggest that the device specifically targets anhydrous tissue, such as calcium and tumour, and spares collagen-rich structures, such as myocardium, vessels, and nerves. In our practice, we prefer using the Barracuda® straight serrated tip for sternotomy cases as it appears to best address

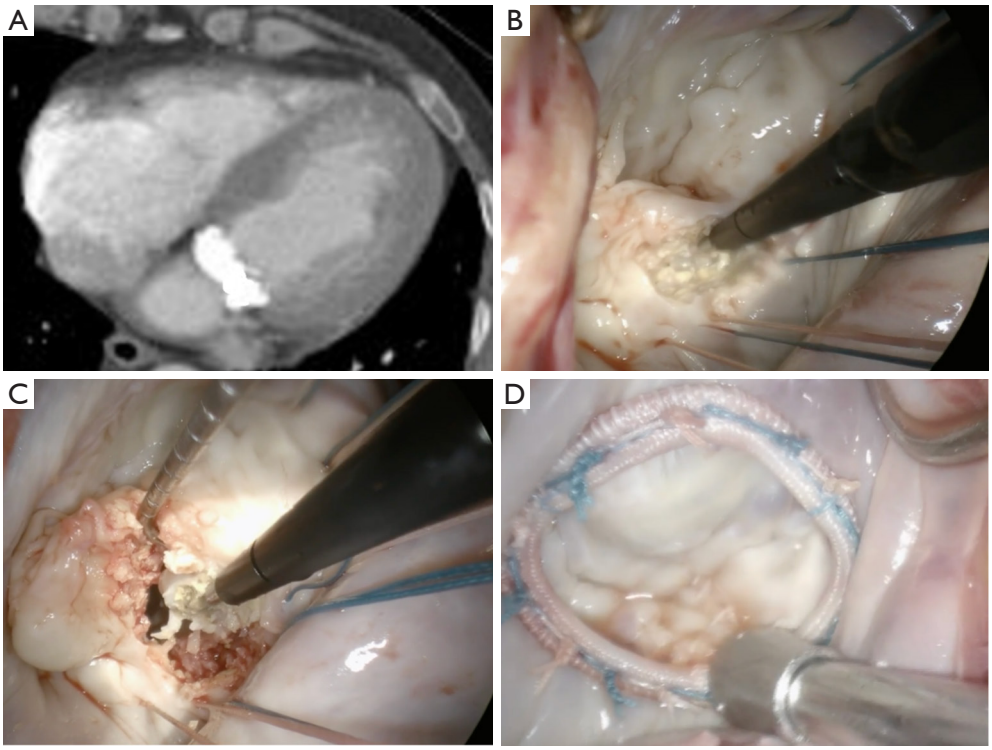

Figure 1 Preoperative image. (A) Axial CT scan demonstrating severe posterior MAC. Intraoperative images. (B,C) Decalcification of the posterior leaflet and annulus using Sonopet device. (D) Mitral valve repair and final saline test with annuloplasty ring. CT, computed tomography; MAC, mitral annular calcification.

dense posterior annular calcification while preserving the integrity of surrounding soft tissues. Our preferred device settings for MAC are 80% power, 70% suction, and 20% irrigation (*Figure 2A*), which is generally higher than other surgical indications. These settings were identified through intraoperative experience to balance the efficiency of decalcification with control and safety. We find this device allows for very precise decalcification and the ability to sculpt the calcium resection to facilitate mitral annular mobility and remodelling, with annuloplasty with perceived reduced risk of injury to the AV groove, myocardium, or circumflex artery.

We have successfully integrated ultrasonic emulsification into both median sternotomy and right anterolateral mini-thoracotomy approaches as well; however, the Sonopet's current shaft length presents a technical limitation in minimally invasive cases when the annulus-to-chest wall distance exceeds 180 mm, restricting its reach in certain patients (*Figure 2B*). In minimally invasive cases, we use the longer Apex 360® tip, with a shaft measuring approximately 20 cm, whereas the Barracuda tip only measures 12 cm, making it difficult to integrate in minimally invasive cases (*Figure 2C,2D*). Overall, the integration of ultrasonic emulsification into the operative workflow was seamless in both open and minimally invasive approaches, with no need for additional procedural steps or devices.

Results

Demographic data

A total of 27 consecutive patients with moderate to severe MAC and severe MR underwent mitral valve surgery and MAC decalcification using ultrasonic emulsification over a 25-month period. Patients mostly had severe MAC (20, 74.7%) and severe MR (26, 96.3%). The mean age was 69.0±10.6 years old. Sex was relatively well matched in our cohort, 55.6% were male, while 44.4% were female. Most patients had preserved left ventricular ejection fraction (LVEF) (57.3%±8.9%) and New York Heart Association (NYHA) class II–IV symptoms (23, 85.2%). Other preoperative characteristics are summarized in *Table 1*.

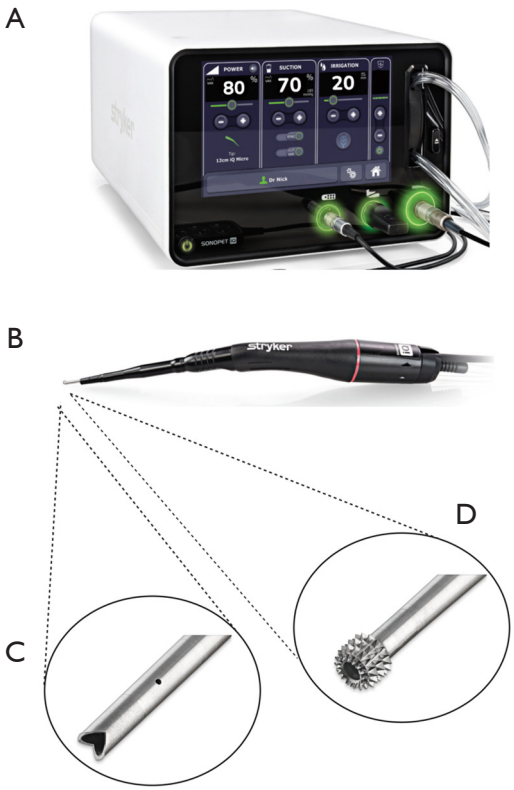

Figure 2 Sonopet Ultrasonic Aspirator® (Stryker). (A) Our preferred device settings for MAC include 80% power, 70% suction, and 20% irrigation. (B) Stryker Sonopet® device. (C) Barracuda tip (12 cm). (D) iQ Apex 360 tip (20 cm). MAC, mitral annular calcification.

Table 1 Baseline characteristics for the Sonopet study cohort

Characteristics	Ultrasonication cohort (n=27)
Age (years)	69.0±10.6
Male	15 (55.6)
BMI (kg/m^2)	26.3±3.8
Atrial fibrillation	7 (25.9)
Chronic obstructive pulmonary disease	5 (18.5)
Cerebrovascular disease	2 (7.4)
Diabetes mellitus	0 (0.0)
Peripheral vascular disease	3 (11.1)
Coronary artery disease	2 (7.4)
NYHA class	
I	4 (14.8)
II	12 (44.4)
III	9 (33.3)
IV	2 (7.4)
Preoperative LVEF (%)	57.3±8.9
Preoperative LVEDD (mm)	50.7±12.6
Preoperative LVESD (mm)	35.9±7.8
MAC	
Moderate	20 (74.1)
Severe	7 (25.9)
MR	
Moderate	1 (3.7)
Severe	26 (96.3)

Data are presented as mean ± SD or n (%). BMI, body mass index; LVEDD, left ventricular ejection diastolic diameter; LVEF, left ventricular ejection fraction; LVESD, left ventricular end systolic diameter; MAC, mitral annular calcification; MR, mitral regurgitation; NYHA, New York Heart Association; SD, standard deviation.

Technical details and perioperative outcomes

Table 2 summarizes detailed intraoperative data. Most operations were elective (92.6%) and via median sternotomy over right anterolateral mini thoracotomy (63% *vs.* 37%). Most mitral valve repairs were for isolated posterior leaflet prolapse (66.7%) or bileaflet prolapse (22.2%). The primary repair strategy included leaflet resection (51.9%) with 25.9% of patients receiving isolated neochords or a mixed strategy of resection with neochords (22.2%). The primary area of MAC decalcification was in the posterior mitral valve annulus (*Figure 3*). Mitral repair was successfully performed in 26 patients (96.3%), with one conversion to replacement (3.7%) due to severe radiation heart disease and poor leaflet quality, while one patient required conversion to sternotomy due to issues with hypotension and poor CPB flows with conversion to central arterial cannulation. At least one minor concomitant procedure was performed in most patients (24, 88.9%), while one major concomitant procedure was performed in six patients (22.2%). The mean CPB time was 159.6±46.8 min, while the mean cross-clamp time was 116.9±46.5 min. On discharge transthoracic echocardiogram (TTE), 96.3% of patients had none or mild residual MR, while one patient (3.7%) had moderate residual MR. The mean coaptation length was 10.3±3.2 mm.

Table 2 Surgical details for Sonopet study cohort

Intraoperative variables	Ultrasonication cohort (n=27)
Approach	
Sternotomy	17 (63.0)
Mini thoracotomy	10 (37.0)
Leaflet repaired	
Posterior leaflet	18 (66.7)
Anterior leaflet	0 (0.0)
Bileaflet	6 (22.2)
Annuloplasty only	1 (3.7)
Conversion to sternotomy	1 (3.7)
Conversion to replacement	1 (3.7)
Second cross-clamp	2 (7.4)
Ring size (mm)	34.7±2.9
Annuloplasty	
Band	11 (40.7)
Ring	16 (59.3)
Primary repair strategy	
Neochord	7 (25.9)
Resection	14 (51.9)
Mixed	6 (22.2)
Plication	0 (0.0)
Commisuroplasty	8 (29.6)
Patch repair	1 (3.7)
AV groove reconstruction	3 (11.1)
Sliding plasty	11 (40.7)
Residual MR > mild	1 (3.7)
Coaptation length (mm)	10.3±3.2
Minor concomitant procedure	
Tricuspid valve repair	6 (22.2)
ASD/PFO	12 (44.4)
Cryoablation	9 (33.3)
LAA closure	11 (40.7)
Major concomitant procedure	
CABG	1 (3.7)
Aortic valve intervention	4 (14.8)
Aortic surgery	3 (11.1)
Total CPB time (min)	159.6±46.8
Cross-clamp time (min)	116.9±46.5

Data are presented as n (%) or mean ± SD. ASD, atrial septal defect; AV, atrioventricular; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; LAA, left atrial appendage; MR, mitral regurgitation; PFO, patent foramen ovale; SD, standard deviation.

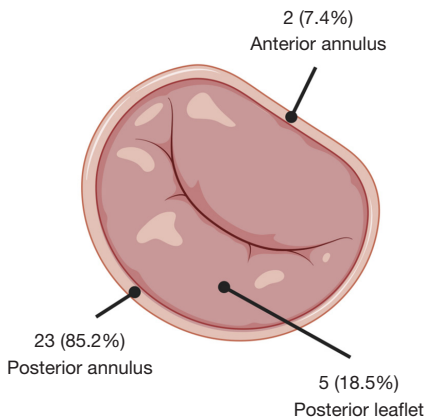

Figure 3 Location of mitral annular decalcification with the Sonopet device.

In our cohort, no deaths were reported at 30 days, and there were no re-interventions for mitral valve dysfunction or mediastinal bleeding. Two patients had respiratory failure, defined as ≥48 hours on a ventilator. There were no instances of renal failure, postoperative MI, or stroke. A total of five patients developed new atrial fibrillation (18.5%). The median length of stay in the intensive care unit (ICU) was one day with a median in-hospital duration of six days. Two patients required permanent pacemaker insertion (7.4%) for third-degree heart block postoperatively. One of these patients underwent a concomitant aortic valve replacement while the other had a concomitant biatrial cryomaze for atrial fibrillation (*Table 3*).

Discussion

Statement and discussion of principal findings

MAC remains one of mitral valve surgery's most technically

Table 3 In-hospital outcomes for Sonopet study cohort

Outcomes	Ultrasonication cohort (n=27)
Death	0 (0.0)
Reintervention	0 (0.0)
Respiratory failure (≥48 hours on ventilator)	2 (7.4)
Wound infection	0 (0.0)
Renal failure requiring RRT	0 (0.0)
Postoperative MI	0 (0.0)
Stroke	0 (0.0)
Atrial fibrillation	5 (18.5)
PPM insertion	2 (7.4)
AV groove disruption	0 (0.0)
ICU stay (days)	1
In-hospital stay (days)	6
ICU days >4	3 (11.1)
Hospital days >10	4 (14.8)

Data are presented as n (%) or median. AV, atrioventricular; ICU, intensive care unit; MI, myocardial infarction; PPM, permanent pacemaker; RRT, renal replacement therapy.

demanding challenges. In this case series of 27 patients with moderate-to-severe MAC, ultrasonic emulsification with the Sonopet device facilitated safe and effective mitral valve reconstruction, with no cases of AV groove disruption, calcific embolization, stroke, reoperation, or in-hospital death. These outcomes compare favorably with historical series involving traditional sharp debridement with a scalpel or electrocautery. We were also able to achieve excellent height of coaptation, a marker associated with improved repair durability over time (17). Moreover, very little residual MR remained in our patients following mitral valve repair.

These findings support the hypothesis that ultrasonic decalcification enables greater preservation of native valve and annular structures, facilitating technically successful repairs in a population historically considered high-risk for complications. Traditionally, several techniques have been described for MAC decalcification (*Table 4*). Techniques for *en-bloc* scalpel resection of MAC were described by Carpentier *et al.*, who reported on 67 patients undergoing mitral valve repair. In this cohort, there were two cases of in-hospital mortality, three cases of perioperative MI, and eight cases of low cardiac output state (18). d'Alessandro *et al.* further reported on 124 patients undergoing mitral valve surgery with MAC of whom 34 patients had extensive MAC involving two or more segments of the mitral annulus, which was decalcified using the Carpentier technique (19). In this series, there were two cases of conversion to mitral valve replacement (19). Furthermore, Feindel *et al.* described a series of 32 mitral valve replacement and 12 repair patients where calcium bar was excised by *en bloc* sharp dissection with five cases of operative mortality (10). Tomšič *et al.* also reported on 75 patients undergoing mitral valve repair with MAC, of which 55 patients (73%) underwent extensive *en bloc* decalcification (20). In this group, there were three deaths, two strokes, and two conversions to mitral valve replacement (20). Finally, a cohort of 625 patients undergoing mitral valve repair for myxomatous mitral valve disease, MAC was noted in 119 patients (19%) and of these conversions to mitral valve replacement occurred in 5 cases (4%) (21). *En-bloc* decalcification remains an appealing technique; however, in our experience, the posterior calcific bar more commonly fragments and fractures into many pieces, potentially increasing the risk for calcific embolization and stroke.

MAC decalcification using rongeurs has also been described. Uchimuro *et al.* reported on a cohort of 61 patients of which five underwent attempted mitral valve repair, and there was one case of conversion to mitral valve replacement due to intraoperative LV rupture (22). There was a total of four in-hospital deaths, two cases of stroke, and requirement for permanent pacemaker in five cases (22). Electrocautery is another conventional strategy for complete excision of the entire calcium bar. Shi *et al.* reported on a group of 38 patients (14 repairs and 24 replacements) with two cases of 30-day mortality, one case of stroke, one patient placed on extracorporeal membrane oxygenation (ECMO), and new renal failure in three patients (23).

Ultrasonic emulsification is a promising adjunct for mitral valve repair and replacement in patients with MAC (7,22,24-26). Devices like Sonopet (Stryker) and CUSA (Integra LifeSciences, Princeton and Plainsboro, NJ, USA) allow focused and controlled decalcification, enabling precise annular remodelling while minimizing the mechanical torque associated with sharp or blunt dissection. We believe this technique better preserves posterior leaflet tissue for reconstruction and may reduce the risk of annular fracture and AV groove disruption, facilitate suture

Table 4 Comparison of contemporary studies investigating mitral annular decalcification

Study	Method	Cohort	Mortality	Stroke	LV rupture	Conversion to replacement
Carpentier (18)	*En-bloc*	Mitral valve repair (n=67)	2 (2.9)	0 (0.0)	0 (0.0)	3 (4.5)
Feindel (10)	*En-bloc*	Mitral valve surgery (n=54) including 12 repairs	5 (9.3)	3 (5.6)	–	–
d'Alessandro (19)	*En-bloc*	Mitral valve surgery (n=124) including 85 attempted repairs	18 (14.5)	7 (5.6)	0 (0.0)	2 (2.3)
Tomšič (20)	*En-bloc*	Mitral valve repair in MAC (n=75)	3 (4.0)	2 (2.7)	0 (0.0)	2 (2.7)
Chan (21)	*En-bloc*	Mitral valve repair (n=625)	0 (0.0)	–	0 (0.0)	19 (3.0)
Uchimuro (22)	Rongeurs	Mitral valve surgery (n=61) including 5 attempted repairs	4 (6.7)	2 (3.3)	1 (1.6)	1 (20.0)
Shi (23)	Cautery	Mitral valve surgery (n=38)	2 (5.3)	1 (2.6)	–	–

Data are presented as n (%). LV, left ventricular.

placement for annuloplasty, and preserve leaflet integrity for valve reconstruction (25-27). Brescia *et al.* reported similar results in a series of 15 patients with severe MAC who underwent mitral valve replacement using ultrasonic emulsification, with no operative mortalities or strokes, in contrast to a cohort treated with traditional decalcification techniques, which had a 10.3% mortality rate and 7.3% of postoperative stroke, highlighting the safety of this technique (27). While TMVR is a contemporary option for high-risk patients, it is limited by anatomical constraints, has poor long-term durability, and is associated with complications such as left ventricular outflow tract (LVOT) obstruction and paravalvular leak (2,3,9). In contrast, ultrasonic aspiration provides a more controlled method for annular remodelling, minimizing AV groove disruption and circumflex artery injury, and potentially expanding the pool of patients eligible for surgical repair.

Limitations of the device and the study

While our early experience with the Sonopet Ultrasonic Aspirator® (Stryker) has been favourable, the device and this study present important limitations. In minimally invasive procedures, a chest wall-to-mitral annulus distance exceeding 180 mm may preclude adequate reach, and the bulky handle can restrict endoscopic exposure. High-quality endoscopic visualization is essential in these cases. Future device modifications—such as extended shafts and slimmer, lower-profile handles—may address these constraints. Moreover, there is a steep learning curve associated with adopting ultrasonic decalcification, particularly in minimally invasive settings. While our results are promising, the findings are limited by the single-centre, single-arm, retrospective nature of the study and the relatively small sample size with a lack of long-term follow-up. These factors limit the generalizability of our findings and preclude definitive conclusions regarding the superiority of our technique over conventional ones.

Implications of the study

Nonetheless, our early experience demonstrates that ultrasonic emulsification can be effectively integrated into both sternotomy and minimally invasive approaches for MAC. Importantly, we believe that it may increase the repairability rate of mitral valves in MAC, which has important implications for patients' survival and quality of life. While prior reports, such as those by Brescia *et al.*, have described the use of ultrasonic aspirators in valve replacement, our series is among the first to demonstrate their utility in facilitating mitral valve repair, particularly in minimally invasive approaches. Ongoing follow-up of our cohort will provide valuable long-term data on durability and repair integrity. Future research should include larger, multicenter studies with long-term outcomes and direct comparisons to standard techniques to better define the role of ultrasonic decalcification in managing MAC. Having been largely absent from prior guidelines, ultrasonic emulsification has recently received a class IIB recommendation in the 2025 American Association for

Thoracic Surgery (AATS) Expert Consensus on surgical management of MAC (9). Our early experience adds to the evidence to support its use in MAC and that it may help to improve mitral repair rates in MAC.

Conclusions

MAC remains one of the most formidable challenges in mitral valve surgery. In this early experience, ultrasonic emulsification and aspiration with the Sonopet Device proved to be a safe and effective adjunct to both open and minimally invasive mitral valve surgery in patients with moderate-to-severe MAC. Despite an initial learning curve, this approach has the potential to expand repair options for patients who might otherwise be relegated primarily to valve replacement. By enabling precise, controlled decalcification while preserving surrounding soft tissue, this technique facilitates high rates of successful valve repair—even in anatomically complex cases—and is now our strategy of choice when tackling MAC.

While technical limitations remain—particularly in minimally invasive cases—the integration of ultrasonic emulsification into our surgical workflow was seamless, with excellent short-term outcomes and no instances of AV groove disruption, stroke, or in-hospital mortality. Our findings suggest that even in heavily calcified valves, mitral repair can be performed safely and effectively, with early markers indicating durable results. Ongoing data collection from our growing cohort will help refine patient selection and standardize technique. Ultimately, larger multicenter studies with long-term follow-up will be essential to confirm durability and establish the role of ultrasonic emulsification in the surgical management of MAC.

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Footnote

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Conflicts of Interest: The authors have no conflicts of interest to declare.

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