Surgical management for mechanical complications of acute myocardial infarction: a systematic review of long-term outcomes

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Background: Mechanical complications following acute myocardial infarction (AMI), though rare, are associated with significant morbidity and mortality. Surgical management remains a mainstay of therapy for these complications. The purpose of this review is to evaluate long-term outcomes data of surgical management for postinfarction free wall rupture, ventricular septal defect, papillary muscle rupture, and pseudoaneurysm.

Methods: An electronic literature search was performed to identify original studies reporting long-term outcomes data of surgical management of one of the four mechanical complications following AMI. Studies were considered to have long-term outcomes if they at minimum included survival or mortality data up to one year.

Results: A total of 285 studies were identified from the literature search. Of these, 29 studies with long-term survival data on surgically managed mechanical complications of AMI are included in the review. The majority of these are retrospective cohort studies or single-center case series. Five studies are included on free wall rupture, 18 on ventricular septal defect, 4 on papillary muscle rupture, and 2 on pseudoaneurysm. Detailed results are tabulated according to complication.

Conclusions: Long-term surgical outcomes of postinfarction mechanical complications remain understudied. Outcomes for ventricular septal defect repair are better represented in the literature than are outcomes for other mechanical complications, though available studies are still limited by small sample sizes and retrospective design. Further research is warranted, particularly for outcomes of acute pseudoaneurysm repair.

Keywords: Acute myocardial infarction (AMI); left ventricular free wall rupture; ventricular septal defect; papillary muscle rupture; pseudoaneurysm

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Introduction

Mechanical complications following acute myocardial infarction (AMI), though rare, are associated with a high mortality rate. Among patients with AMI, those with large infarcts, late presentation, or lack of adequate revascularization remain at risk for mechanical complications. With the advent of percutaneous coronary intervention as standard therapy for ST-elevation myocardial infarction (STEMI), the incidence of mechanical complications has fallen significantly (1). Nevertheless, case fatality rates for post-AMI mechanical complications have remained largely unchanged, despite increased use of mechanical circulatory support and refined surgical techniques and outcomes (2,3). Though transcatheter interventions are gaining popularity, surgical management remains the mainstay of therapy for these complications, with a frequently dismal prognosis when managed medically. Short-term outcomes for surgical management of these complications have been well studied, but long-term outcome data is relatively scarce. The purpose of this review is to evaluate the existing literature on long-term outcomes of surgical management for the mechanical complications of AMI. We will present these findings after a brief review of the four complications.

Left ventricular (LV) free wall rupture (FWR)

LV FWR can be classified as ‘blow-out’ type, in which patients present with profound acute cardiogenic shock leading to cardiac arrest, or as ‘oozing’ type, in which presentation is less dramatic but still involves hemodynamic instability and pericardial effusion. Depending on their clinical status, patients may need to be bridged with intra-aortic balloon pump (IABP) or extracorporeal membrane oxygenation (ECMO) support but will ultimately require surgical intervention (4).

The goals of surgical management of LV FWR include closing the defect, relieving tamponade, anchoring the repair in healthy tissue, minimizing distortion of ventricular geometry, and preventing pseudoaneurysm or re-rupture. Two general surgical strategies are sutured and sutureless repair. Sutured repair techniques include linear closure, infarctectomy and closure, or patch closure. In sutureless repair, a patch is applied with surgical glue to cover the defect; alternatively, a collagen sponge patch, such as TachoSil, is applied. Sutureless repair is more suitable for oozing-type FWR, with obvious limitations in controlling bleeding and preventing re-rupture in blow-out type. Advantages of sutureless repair include avoidance of cardiopulmonary bypass (CPB) and thus of systemic heparinization, as well as avoidance of suturing on fragile, infarcted myocardium. Despite advances in surgical management of FWR, operative mortality is still quoted as high as 35% (4). A recent best evidence review by Nasir *et al.* demonstrated improved short- and mid-term survival as surgical technique has evolved over time to sutureless repair without the use of CPB. Data regarding long-term outcomes remains relatively limited (5).

Ventricular septal defect (VSD)

VSD usually presents three to five days following AMI. Afterload reduction with medications, IABP, and/or ECMO support is key in reducing shunting and pulmonic-to-systemic flow ratio. Regardless of strategy, afterload reduction is only a temporizing measure until the defect can be closed. Without closing the defect, mortality approaches 80% at 30 days (2). Long term mortality rates with medical management have been estimated at 94% in the multicenter Global Utilization of Streptokinase and TPA for Occluded Coronary Arteries trial (6) and 96% in the SHOCK registry (7).

Operative mortality associated with this complication remains high, around 40% (8,9). A recent systematic review of short-term outcomes after VSD repair demonstrated an operative mortality around 38%. The authors found that operative mortality was unchanged over the last two decades [2001–2018] as compared to the preceding three [1971–2000]. There was no difference in operative mortality among patients who did and did not undergo concomitant CABG (10). Long-term outcome data were not assessed. How concomitant CABG, timing of surgery, and technique for repair influence long-term outcomes after VSD repair are all questions that remain to be answered within the literature.

Papillary muscle rupture (PMR)/acute mitral regurgitation

PMR with resultant acute mitral regurgitation (MR) is another life-threatening complication of AMI, with in-hospital mortality reported to be between 10% and 40% (11,12). Many patients present with pulmonary edema and may quickly progress to cardiogenic shock. Papillary muscle rupture may be complete, with rapid clinical deterioration, or partial, with a more subacute, stable presentation. Initial management again involves afterload reduction, as well as preload reduction. This can be accomplished with IABP support. Patients often require emergent temporary mechanical circulatory support as a bridge to surgery.

Surgical management is the mainstay of therapy (2). In the APEX-AMI trial (Assessment of Pexelizumab in Acute Myocardial Infarction), patients who underwent surgical repair had markedly improved survival at 90 days (69%) as compared to those who were treated medically (33%) (13). While chordal-sparing mitral valve replacement is considered to be the standard, mitral valve repair or replacement with a bioprosthetic or mechanical valve are all approaches that have been used for postinfarction PMR. Prior series have reported similar or improved operative mortality when concomitant CABG is performed (2,14).

Pseudoaneurysm

Left ventricular pseudoaneurysms may occur after transmural infarction, resulting in cardiac rupture contained by pericardial adhesions (15). While acute rupture of the anterior wall is typically immediately fatal, pseudoaneurysms of the inferior or lateral wall can remain undiagnosed for months. Pseudoaneurysms following AMI typically require immediate surgical repair due to their progressive risk of rupture.2 Surgical repair may be performed primarily with pledgeted sutures or with the use of GoreTex, Dacron, autologous, or bovine pericardial patches.

Methods

This systematic review follows the reporting guidelines designated by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (16).

Eligibility criteria

Eligible studies for the current systematic review included original studies which reported long-term outcomes of surgical management of one of the four mechanical complications following acute myocardial infarction (i.e., left ventricular free wall rupture, ventricular septal defect, papillary muscle rupture/acute mitral regurgitation, and pseudoaneurysm). Studies were considered to have long-term outcomes if they at minimum included survival or mortality data up to one year. Studies with short-term outcomes data only were not included. Studies on transcatheter management alone were also not included. Publications were limited to those involving human subjects and in the English language. Case reports and case series with fewer than five patients were excluded. Editorials and previous reviews were also excluded.

Literature search strategy

An electronic search was performed in July 2021 using Ovid Medline, with the assistance of a health sciences librarian (H.V.) experienced in systematic reviews. The concepts used to develop the search were: acute myocardial infarction, mechanical complications (including ventricular septal defect, pseudoaneurysm, papillary rupture, acute mitral regurgitation, and free wall rupture), and surgery. A combination of Medical Subject Headings (MeSH) and title, abstract, and keyword terms were used to create the search. The search was limited to studies dated 2010 to July 2021. A copy of the search strategy is available (Appendix 1).

Selection process

Two investigators (SY, KK) independently screened all abstracts for study selection. Full text review was also independently performed by SY and KK. Any discrepancies between these two investigators were resolved by the senior investigator (GJA).

Data collection process

All data were extracted from article texts and tables by two independent reviewers (SY and KK). Any discrepancies between these two investigators were resolved by the senior investigator (GJA).

Data items

The primary outcome of interest was long-term survival. Data were also collected on study demographics, patient age, preoperative characteristics, operative techniques, operative mortality, and other postoperative outcomes or study findings.

Quality assessment and risk of bias assessment

The Newcastle-Ottawa Scale (NOS), a tool for quality and risk of bias assessment recommended by the Cochrane collaboration, was utilized for retrospective cohort studies. Content validity and interrater reliability have been established for this tool (17,18).

Effect measure and synthesis methods

Meta-analysis and statistical synthesis was not performed, nor were effect sizes calculated.

The results of individual studies were tabulated according to type of mechanical complication.

Results

Study selection and study characteristics

A total of 285 studies were identified from the literature search. Of these, 29 were included in the review (*Figure 1*).

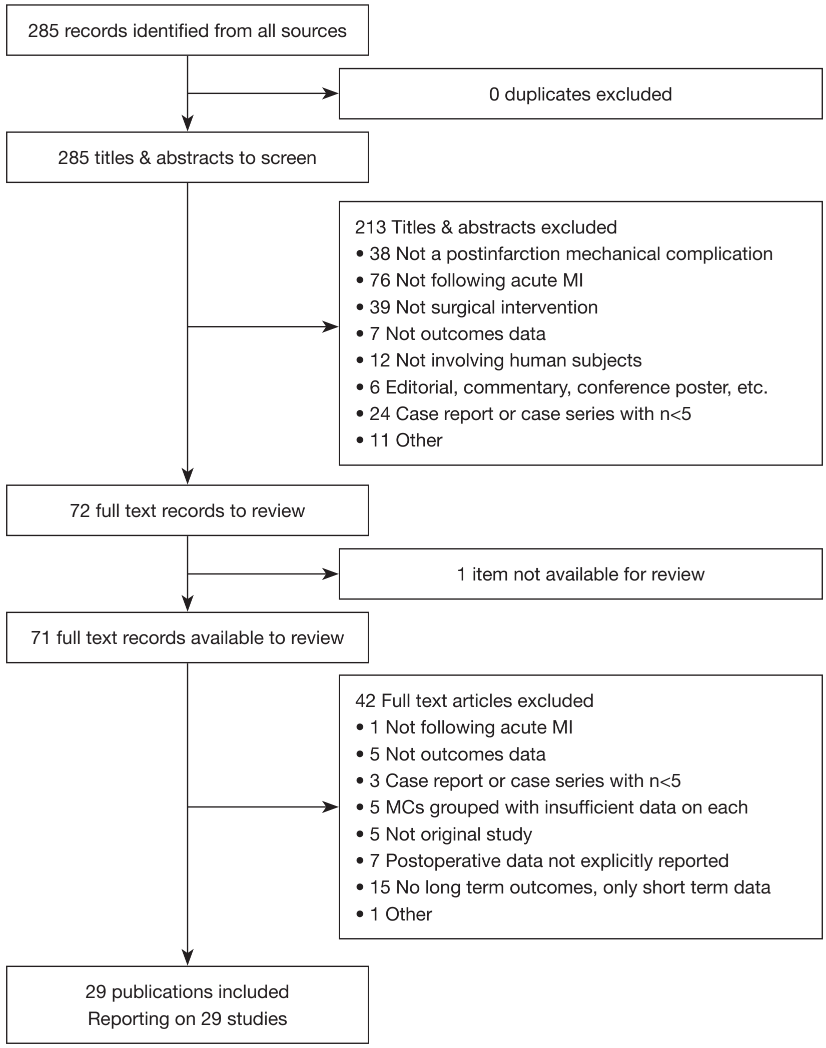

Figure 1 Prisma flowchart. MI, myocardial infarction.

Most of the studies included were retrospective cohort studies or case series of patients managed at a single institution or at two institutions. One of the studies was a retrospective review of the Society of Thoracic Surgeon's database combined with Medicare data (19). No randomized studies were identified. The details of each study are tabulated according to type of mechanical complication (*Tables 1-4*). The findings for each complication are summarized below.

Study quality and risk of bias

The NOS was applied to all retrospective cohort studies, with the caveat that most of these studies do not have a control group. Rather, many of these studies report outcomes for a single cohort of patients undergoing surgical intervention and then perform analyses to determine which variables within this patient group are predictive of outcomes. For these studies, one star was awarded for comparability if multivariable regression was used to adjust for confounders; otherwise, zero stars were awarded for comparability. Similarly, the maximum number of stars that were given for selection in a study with no control group was three. The results of this assessment have been tabulated for each cohort study (*Table 5*). The majority of studies in this review were awarded 3 out of 4 stars for selection, 0–1 out of 1 star for comparability, and 3 out of 3 stars for outcome.

Table 1 LV free wall rupture

Study	Population	N	Age, years	Operative details	Operative mortality	Follow up time	Survival at follow up
Retrospective cohort studies							
Kacer, 2020 (20)	Single center, Prague 2006 to 2017	19	64	• 73.7% ventriculotomy, on bypass (7 endoventricular plasty, 6 direct suture, 1 patch closure) • 26.3% sutureless repair • Concomitant CABG: 36.8%	5 (26.3%)	Median f/u: 45 months	Alive at f/u: 14/14 (100.0%)
Okamura 2019 (21)	Single center, Saitama 2001 to 2016	35	71.5±9.5	• All sutureless repair using collagen sponges, without bypass	6 (17.1%)	Median f/u: 3.4 years	Overall survival: 1-year: 71.4%, 5-year: 68.6%, 10-year 62.9%, 6 late deaths at f/u
Formica, 2018 (22)	Single center, Italy 2000 to 2016	35	68.3±8.5	• 60.0% on bypass • 45.7% patch and glue • 54.3% direct suture • Concomitant CABG: 42.9%	12 (34.3%)	Overall mean f/u: 8.3 years	Overall survival: 5-year: 53.2%±8.6%; 10-year: 49.1%±8.9%
Case series							
Raffa, 2013 (23)	Single center, Italy	6	60–83	• TachoSil patch • Beating-heart 50% • Full bypass 50% • Concomitant CABG: 0%	1 (16.7%)	Mean f/u: 24±18 months	All 5 discharged patients alive at f/u
Zoffoli, 2012 (24)	Single center, Italy 1997 to 2011	25	65±9.1	• Double-layer AKA “patch and glue” • All beating-heart • Concomitant CABG: 8.0%	3 (12.0%) [low EF]	Mean late f/u: 6.7 years	Mortality at 6 months: 4 (16.0%) Mortality at late f/u: 8 (32.0%)

CABG, coronary artery bypass grafting; f/u, follow up; EF, ejection fraction.

Left ventricular free wall rupture

Our review identified five original studies with long-term outcome data for surgically managed FWR (*Table 1*) (20-24) Operative mortality among the studies ranged from 12–34%. In the study by Okamura *et al.*, overall survival of 35 patients managed with sutureless repair without the use of CPB at 1, 5, and 10 years was 71.4%, 68.6%, and 62.9%, respectively. On multivariate analysis, age and re-rupture were identified as independent predictors of decreased survival. All patients in this study had the oozing-type of FWR except for two, and these were two of the six patients that re-ruptured (21). In the study by Formica *et al.*, overall survival of 35 patients at 5 and 10 years was 53.2%±8.6% and 49.1%±8.9%, respectively. Operative mortality was twice as high as that in the series by Okamura. Almost half of the patients in this series had the blow-out type of FWR, with sutured repair, as well as CPB, utilized in most cases (22).

Ventricular septal defect

Our review identified 18 original studies with long-term outcome data on surgically managed postinfarction VSD (19,25-41). One of these studies was a retrospective review of the Society of Thoracic Surgeons’ (STS) database linked with Medicare data which involved 537 patients, 65.7% of whom underwent concomitant CABG. Operative mortality

Table 2 Ventricular septal defect

Study	Population	N	Age, years	Operative details	Operative mortality	Follow up time	Survival at follow up
Retrospective cohort studies							
Arnaoutakis, 2020 (19)	STS Database and Medicare data 2008 to 2012	537	74±5	• Elective: 36.1% • Urgent: 38.2% • Emergent: 23.8% • Salvage: 1.9% • Concomitant CABG: 65.7%	157 (29.2%)		1-year mortality: overall: 210 (39.1%), elective: 25 (12.9%), urgent: 88 (42.9%), emergent: 89 (69.5%), salvage: 8 (80.0%)
Bisoyi, 2020 (25)	Single center, India 2010 to 2014	21		• 76.2% acute (within 7 days of MI) • 100% infarct exclusion • Concomitant CABG: 81.0%	5 (23.8%)	Mean f/u: 5 years	Alive at f/u: 16/16 (100.0%)
Dogra, 2019 (26)	Single center, India 2012 to 2018	35	58±11	• Avg time 11 days from MI • 74.3% infarct exclusion • 20.0% septal patch • 6.0% direct closure • Concomitant CABG: 62.9%	46%		1-year mortality: 49%
Furui, 2018 (27)	Single center, Japan 2003 to 2016	24	72.6±10.4	• 54.2% delayed (2 weeks after MI) • Patch closure • Concomitant CABG: 50.0%	30 days: 1 (4.2%) Long-term hospital mortality: 3 (12.5%)	Mean f/u: 66± 54 months	Overall survival: 1-year: 82.9%, 5-year: 77.8%, 10-year: 64.8%
Pojar, 2018 (28)	Single center, Czech Republic 1996 to 2016	39	68.4±9.9	• Emergent 33.3% • Infarct exclusion • Concomitant CABG: 31.0%	14 (35.59%)	Median f/u: 55.2 months	Overall survival: 1-year: 50%, 5-year: 38%
Isoda, 2017 (29)	2 centers, Japan 2001 to 2013	24	73.5	• "Sandwich" technique via RV incision • Concomitant CABG: 16.7%	0 (0.0%)		1-year mortality: 25.0%
Okamoto, 2016 (30)	Single center, Japan 2004 to 2015	21		• 23.8% elective (>7 days after MI) • Triple patch (modified infarct exclusion) • Concomitant CABG: 38.1%	5 (23.8%)	Mean f/u: 43.5±36.1 months	Overall survival: 3-year: 70.8%, 8-year: 57.9%
Huang, 2015 (31)	Single center, Taiwan 1995 to 2013	47	68.9±9.5	• 5.3±10.4 days b/n MI and surgery • Emergent 87.2% • Infarct exclusion • Concomitant CABG: 57.4%	17 (36.2%)	Mean f/u: 99.1 months	Overall survival: 6-year: 41.1±2.2%
Isoda, 2015 (32)	2 centers, Japan 2001 to 2013	25	73.6	• Avg time from MI to surgery 2.1 days • "Sandwich technique" via RV incision • Concomitant CABG: 20.0%	0 (0.0%) Long term hospital mortality: 7 (28.0%)	f/u rate: 96% Mean f/u: 4.2±3.7 years	Overall survival: 1-year: 71±9%, 5-year: 65±10%, 10-year: 56±12%

Table 2 (*continued*)

Table 2 (*continued*)

Study	Population	N	Age, years	Operative details	Operative mortality	Follow up time	Survival at follow up
Takahashi, 2015 (33)	Single center, Germany 1982 to 2012	52	67±10	• Median interval b/n MI and surgery 8 days • Suture closure *vs.* varied patch repairs • Concomitant CABG: 65.4%	19 (36.5%)	Mean f/u: 7.8±7.7 years	Actuarial survival (n=33): 1-year: 91%, 5-year: 75%, 10-year: 31% Overall survival: 1-year: 58%, 5-year: 47%, 10-year: 20%
Kim, 2015 (34)	Single center, South Korea 2001 to 2011	23	68±9	• Avg time from MI to surgery 3.4± 2.9 days • Infarct exclusion [21], patch [2] • Concomitant CABG: 73.9%	1 (4.3%)	Mean f/u: 26.2±18.6 months	Overall survival: 1-year: 95.5%, 5-year: 82.0%, 7-year: 65.6%
Iwaki, 2014 (35)	Single center, Japan 2002 to 2011	19	72.6±3	• Infarct exclusion; • Compared biventricular [6] *vs.* LV [13] approaches • Concomitant CABG: 47.3%	3 (15.8%)	f/u rate: 87.5% Mean f/u: 35.3± 8.3 months	Overall survival: 5-year: 79%
Sharma, 2013 (36)	Single center, Rochester 2000 to 2011	20	65.3±10 (survivors) 65.6±1 (non-survivors)	• Patch closure via transatrial [8] *vs.* transventricular [12] approach • Concomitant CABG: 35.0%	5 (20.0%)		1 death at 7 years
Sathananthan, 2013 (37)	Single center, New Zealand 1992 to 2012	18		• Patch closure through left ventriculotomy	7 (38.9%)		5 additional patients died after discharge Overall mortality: 75%
Park, 2013 (38)	Single center, Korea 1991 to 2012	34	67.1±8.0	• Infarct exclusion	7 (20.6%) Long-term hospital mortality: 10 (29.4%)	Median f/u: 4.8 years	9 patients died after discharge Overall survival: 5-year: 54.4%±8.8%, 10-year: 44.3%±8.9%
Case series							
Hosoba, 2013 (39)	Single center, Japan 2008 to 2012	15	76±10	• Extended sandwich patch repair through right ventriculotomy	3 (20.0%)	Mean f/u: 17±15 months	Overall survival: 3-year: 76%
Asai, 2012 (40)	Single center, Japan 2008 to 2011	12	76±11	• Extended sandwich patch • Concomitant CABG: 83.3%	3 (25.0%)	Mean f/u: 12±14 months	No deaths during f/u
Isoda, 2012 (41)	Single center, Japan 2001 to 2010	7	70.9	• "sandwich technique" via RV incision • Concomitant CABG: 28.6%	0 (0.0%) Long-term hospital mortality: 1 (14.3%)	Mean f/u: 48.1 months	Long-term survival: 5/7

STS, Society of Thoracic Surgeons; CABG, coronary artery bypass grafting; f/u, follow up; avg, average; b/n, between.

Table 3 Papillary muscle rupture

Study	Population	N	Age, years	Operative details	Operative mortality	Follow up time	Survival at follow up
Retrospective cohort studies							
Sultan, 2018 (42)	Single center, Pittsburgh 2011 to 2017	24	61.8±12.5	• All patients operated on day of PMR diagnosis • MV replacement: 70.8% • MV repair: 29.2% • Concomitant CABG: 54.2%	3 (12.5%)	Mean f/u: 2.4±1.96 years	1 and 3-year freedom from mortality: 78.9%
Leroux, 2019 (43)	Single center, Quebec 2000 to 2016	37	63.5±11	• Avg 7.4 days from MI to PMR, 2.2 days from PMR to surgery • All MV replacement ■ Bioprosthetic: 12 ■ Mechanical: 25 • Concomitant CABG: 81.0%	7 (18.9%)		Overall survival (cPMR): 1-year: 72%, 3-year: 67%, 5-year: 67% (pPMR): 1-year: 84%, 3-year: 84%, 5-year: 74%
Bouma, 2015 (44)	Single center, Netherlands 1990 to 2014	50	64.7±10.8	• Urgent: 22.0% • Emergent: 62.0% • Salvage: 4.0% • MV repair: 20.0% • MV replacement: 80.0% ■ Mechanical: 36 ■ Bioprosthetic: 4 • Concomitant CABG: 48.0%		f/u rate: 100% Mean f/u: 7.1±6.8 years	Overall survival: 1-year: 71.9%±6.4%, 5-year: 65.1%±6.9%, 10-year: 49.5%±7.6%, 15-year: 36.1%±8.0%, 20-year: 23.7%±9.2%
Case series							
Bouma, 2013 (45)	Single center, Netherlands 1990 to 2010	9	63.5±14.2	• Urgent/emergent: 77.8% • MV repair • Concomitant CABG: 55.6%	0 (0.0%)	F/u rate: 100% Mean f/u: 8.7±6.1 years	Overall survival: 1-year: 100%, 5-year: 83.3%±15.2%, 10-year: 66.7%±19.2%, 15-year: 44.4%±22.2%

CABG, coronary artery bypass grafting; f/u, follow up; PMR, papillary muscle rupture; cPMR, complete papillary muscle rupture; pPMR, partial papillary muscle rupture; MV, mitral valve; avg, average.

in this series was 29.2%, and overall 1-year mortality was 39.1%. In many of the smaller series, Kaplan-Meier estimates of overall survival at 1, 5, and/or 10 years were reported (*Table 2*).

Papillary muscle rupture/acute mitral regurgitation

Our search identified four original studies with long-term outcomes data for surgical management of postinfarction PMR (*Table 3*) (42-45). Operative mortality in the studies ranged from 0 to 19%. In the study by Sultan *et al.*, 1- and 3-year freedom from mortality was 78.9% and from all-cause readmission was 54.6%. In the other three studies, overall survival was greater than 70% at 1 year and greater than 65% at 5 years. In the 2015 study by Bouma *et al.*, concomitant CABG was not a predictor of overall survival.

Pseudoaneurysm

Our review identified only two original articles reporting

Table 4 Pseudoaneurysm

Study	Population	N	Age, years	Operative details	Operative mortality	Follow up time	Survival at follow up
Retrospective cohort studies							
Fedakar, 2010 (46)	Single center, Istanbul 1985 to 2008	22	64.0±8.7	• 22.7% early (w/in 2 weeks of MI) • All on full bypass • Primary suture closure, dacron or pericardial patches	6 (27.3%)		In the 16 hospital survivors, mean survival was 61.9±41.4 months
Case series							
Prifti, 2017 (47)	Single center, Albania 2006 to 2016	13	61±7.6	• 30.8% early (w/in 2 weeks of MI) • Direct pledgeted sutures or varied patch closures • Concomitant CABG: 92.3%	4 (30.8%)	1 and 3 years	2 deaths

CABG, coronary artery bypass grafting; w/in, within.

outcomes of surgically managed pseudoaneurysm following acute MI (46,47). In both studies, outcomes of early/acute pseudoaneurysms (identified within the first two weeks after MI) as well as late/chronic pseudoaneurysms were reported. In the study by Prifti *et al.*, only four patients (30.8%) presented with acute, rather than chronic, pseudoaneurysm, and in the study by Fedakar *et al.*, only five patients (22.7%) presented with acute pseudoaneurysm. Operative mortality in the study by Prifti was 30.8% and in the study by Fedakar was 27.3%. The majority of patients who survived to discharge were still alive at 3 years in both studies.

Discussion

Long-term outcomes of surgical management for mechanical complications of acute MI remain poorly understood. This review demonstrates that available data is limited to small retrospective cohort studies and case series. The literature is particularly limited regarding outcomes of LV pseudoaneurysm repair following acute MI. Of the four mechanical complications, outcomes of VSD repair after acute MI have been explored the most, and the following discussion will thus focus on this complication.

Whether concomitant CABG during time of surgical repair improves long-term outcomes remains to be fully understood (10). In the STS database review, older age, emergent or salvage operative status, and concomitant CABG all were strong predictors of 1-year mortality. Importantly, patients who underwent emergent or salvage operation were more likely to have multivessel coronary disease and undergo concomitant CABG. Thus the patient's clinical status at time of operation may have confounded the true association of CABG with 1-year mortality in this study (19). In the study by Huang *et al.*, total revascularization of stenotic coronary arteries was associated with significantly improved late survival (31). On the other hand, incomplete revascularization was shown to be the best predictor of 30-day mortality in the study by Takahashi *et al.* (33). Together, these findings may suggest that concomitant CABG can yield favorable outcomes if complete revascularization is performed, or adverse outcomes if incomplete revascularization is performed. The latter approach may prolong operative and CPB times while sub-optimally treating coronary artery disease, thus potentially decreasing the chances of cardiac recovery. Overall, however, the majority of studies identified demonstrated no long-term survival benefit with concomitant CABG (25,26,28,33,48). This coincides with the findings of a recent systematic review on repair of postinfarction VSD with and without CABG, namely, that concomitant CABG did not have a significant effect on survival (49).

Additionally, the question of optimal timing of surgical repair for postinfarction VSD, as well as for other postinfarction mechanical complications, remains in debate. It has been postulated that delayed repair, if feasible, may be preferable, as it allows for scar formation and thus may avoid suture placement through freshly infarcted friable

Table 5 Newcastle-Ottawa Scale assessment for all retrospective cohort studies

Study	Selection	Comparability	Outcome
Kacer/2020	★★★		★★★
Okamura/2019	★★★	★	★★★
Formica/2017	★★★	★	★★★
Arnaoutakis/2020	★★★	★	★★★
Bisoyi/2020	★★★	★	★★★
Dogra/2019	★★★	★	★★
Furui/2018	★★★	★	★★★
Pojar/2018	★★★	★	★★★
Isoda/2017	★★★		★★★
Okamoto/2016	★★★		★★★
Huang/2015	★★★	★	★★
Isoda/2015	★★★		★★★
Takahashi/2015	★★★	★	★★★
Kim/2015	★★★		★★★
Iwaki/2014	★★★		★★★
Sharma/2013	★★★		★★
Sathananthan/2013	★★★★		★★
Park/2013	★★★	★	★★★
Sultan/2018	★★★		★★★
Leroux/2019	★★★★		★★★
Bouma/2013	★★★	★	★★★
Fedakar/2010	★★★		★★★

tissue. Prior studies, including a recent review of the STS database, have shown decreased mortality when surgery is delayed for a week than when performed immediately for postinfarction VSD, though selection and survival bias may have contributed to this finding (50). One study in this review also demonstrated that shorter time from MI to surgery was an independent predictor of both 30-day and long-term mortality (48).

The influence of surgical technique on long-term outcomes is also not known. Several different repair techniques are available for the management of VSD, including primary repair, patch closure, and infarct exclusion. Repair may also be approached through various incisions, including atrial, left ventricular, right ventricular, or biventricular. A variety of these techniques were utilized in the identified studies. One of the techniques reported in studies by Isoda *et al.* (41,32,29), Hosoba *et al.* (39), and Asai *et al.* (40), is the "sandwich" repair, performed through a right ventriculotomy. This technique is thought to avoid the common issues associated with left ventricular approach, namely distortion of left ventricular geometry and bleeding. However, concerns of the right ventricular approach include thrombus formation at the RV patch as well as right ventricular dysfunction (41,40). In one study of the "sandwich" repair technique, Isoda *et al.* did find that major residual leak, which was correlated with patch-to-VSD size, was also correlated with 1-year mortality (29). Unfortunately, direct comparison of techniques is limited by small study sizes and inability to randomize.

Limitations

This review has several important limitations. Significant time constraints resulted in the abbreviation of the following steps: Ovid Medline was the only database interrogated, leaving the possibility of other studies that were potentially not discovered; reference lists of each identified article were not reviewed for additional potentially relevant articles; an interrater reliability test was not conducted prior to title/abstract screening. The application of quality and risk bias assessment tools was also limited and was not applied to case series. Furthermore, this is a systematic review without meta-analysis; the lack of an analytic component limits the ability to quantitatively synthesize and summarize the outcomes of all reviewed studies. However, as this review covered four separate complications each with limited original data available, tabulation of the outcomes was felt to be an appropriate method of summarizing the literature for this rare and specific topic. Lastly, 'long-term outcomes' was somewhat arbitrarily defined to include studies with survival or mortality data up to a minimum of one year.

Conclusions

While it is known that mechanical complications following acute MI are associated with significant in-hospital morbidity and mortality, long-term outcomes after surgical management of these complications remain understudied. Of the four mechanical complications, outcomes of ventricular septal defect repair after acute MI have been explored the most. The available studies suggest that concomitant CABG at the time of VSD repair may potentially be associated with worse survival if incomplete revascularization is performed and with improved survival if complete revascularization is performed. Additionally, delayed VSD repair may be associated with better survival than immediate repair. However, further research is warranted, as the existing literature is limited to small retrospective cohort studies and case series. Furthermore, numerous approaches to management and inconsistent methods of reporting outcomes across studies limit synthesized interpretation of the findings. The literature is particularly limited regarding outcomes of LV pseudoaneurysm repair following acute MI, and future studies must distinguish outcomes of patients who present with acute versus chronic pseudoaneurysms.

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Footnote

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Supplementary

Appendix 1 Summary of databases searched

Table	Vendor/Interface	Database	Date searched	Database update	Searcher(s)
1a	Ovid	Medline	July 6, 2021	1946 to July 02, 2021	Helena M. VonVille; Sarah Yousef

Note: This template is based on: Niederstadt C, Droste S. Reporting and presenting information retrieval processes: the need for optimizing common practice in health technology assessment. Int J Technol Assess Health Care. 2010;26(4):450-7.

Table 1a Medline® search strategy	
Provider/Interface	Ovid
Database	Medline®
Date searched	July 6, 2021
Database update	1946 to July 02, 2021
Search developer(s)	Helena M. VonVille; Sarah Yousef
Limit to English	Yes
Date Range	2000–2022
Publication Types	Case reports were excluded
Search filter source	No search filter used

1	myocardial infarction/ or anterior wall myocardial infarction/ or inferior wall myocardial infarction/ or non-st elevated myocardial infarction/ or st elevation myocardial infarction/
2	((heart adj1 attack*) or (myocardial adj1 infarct*) or (post adj1 infarction*) or postinfarction*).ti,ab,kf.
3	1 or 2
4	Aneurysm, False/su or "Heart Rupture, Post-Infarction"/su or Mitral Valve Insufficiency/su or Heart Septal Defects, Ventricular/su
5	3 and 4
6	Aneurysm, False/ or "Heart Rupture, Post-Infarction"/ or Mitral Valve Insufficiency/ or Heart Septal Defects, Ventricular/
7	((acute adj2 regurgitation) or ((cardiac or heart) adj1 rupture*) or (false adj1 aneurysm*) or pseudoaneurysm* or (free adj1 wall adj1 rupture*) or (mechanical adj1 complication*) or (papillary adj2 rupture*) or (ventricular adj1 septal adj1 defect*)).ti,ab,kf.
8	6 or 7
9	3 and 8
10	((surgical or surgery) adj3 (correction* or repair* or strateg* or treatment*)).ti,ab,kf.
11	9 and 10
12	(5 or 11) not case reports/
13	limit 12 to (english language and yr="2000-2020")

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