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Surgical treatment for post-infarction papillary muscle rupture: a multicentre study

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MYOCARDIAL REVASCULARIZATION

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Key question

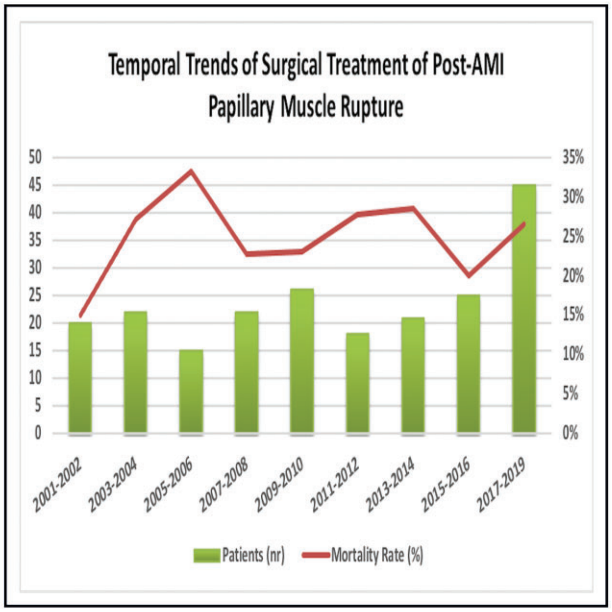
What is the trend in in-hospital mortality for patients who have cardiac surgery for post-AMI papillary muscle rupture (PMR)?

Key finding(s)

Cardiac surgery for post-AMI PMR carries a high in-hospital mortality that did not improve substantially over time.

Take-home message

Future efforts should be directed towards improving management strategies; whenever possible, additional CABG should be performed.



Abstract

OBJECTIVES: Papillary muscle rupture (PMR) is a rare but potentially fatal complication of acute myocardial infarction. The aim of this study was to analyse the patient characteristics and early outcomes of the surgical management of post-infarction PMR from an international multicentre registry.

METHODS: Patients underwent surgery for post-infarction PMR between 2001 through 2019 were retrieved from database of the CAUTION study. The primary end point was in-hospital mortality.

RESULTS: A total of 214 patients were included with a mean age of 66.9 (standard deviation: 10.5) years. The posteromedial papillary muscle was the most frequent rupture location (71.9%); the rupture was complete in 67.3% of patients. Mitral valve replacement was performed in 82.7% of cases. One hundred twenty-two patients (57%) had concomitant coronary artery bypass grafting. In-hospital mortality was 24.8%. Temporal trends revealed no apparent improvement in in-hospital mortality during the study period. Multivariable analysis showed that preoperative chronic kidney disfunction [odds ratio (OR): 2.62, 95% confidence interval (CI): 1.07–6.45, $P = 0.036$], cardiac arrest (OR: 3.99, 95% CI: 1.02–15.61, $P = 0.046$) and cardiopulmonary bypass duration (OR: 1.01, 95% CI: 1.00–1.02, $P = 0.04$) were independently associated with an increased risk of in-hospital death, whereas concomitant coronary artery bypass grafting was identified as an independent predictor of early survival (OR: 0.38, 95% CI: 0.16–0.92, $P = 0.031$).

CONCLUSIONS: Surgical treatment for post-infarction PMR carries a high in-hospital mortality rate, which did not improve during the study period. Because concomitant coronary artery bypass grafting confers a survival benefit, this additional procedure should be performed, whenever possible, in an attempt to improve the outcome.

Clinical trial registration: clinicaltrials.gov: NCT03848429.

Keywords: Papillary muscle rupture • Mitral valve surgery • Acute mitral regurgitation

ABBREVIATIONS

AMI	Acute myocardial infarction
CABG	Coronary artery bypass grafting
CAD	Coronary artery disease
CI	Confidence interval
ECMO	Extracorporeal membrane oxygenation
LCOS	Low cardiac output syndrome
MC	Mechanical complications
MCS	Mechanical circulatory support
MV	Mitral valve
MVr	Mitral valve repair
MVR	Mitral valve replacement
OR	Odds ratio
PCI	Percutaneous coronary intervention
PMR	Papillary muscle rupture
SD	Standard deviation
STEMI	ST-elevation myocardial infarction

INTRODUCTION

Papillary muscle rupture (PMR) is an infrequent but life-threatening mechanical complication (MC) of acute myocardial infarction (AMI) [1]. With the advent of percutaneous coronary intervention

(PCI) reperfusion era, PMR has become increasingly rare, with an estimated incidence of 0.01–0.05% [2]. Usually, it occurs within a week after AMI, frequently as a progression of inferior AMI, and with posteromedial papillary muscle (PM) involvement. Since PMR may suddenly evolve into haemodynamic deterioration due to severe acute mitral regurgitation (AMR), leading to pulmonary oedema and cardiogenic shock, prompt haemodynamic stabilization followed by surgical intervention represents the cornerstone of the treatment [1, 3, 4]. Because of the rarity of this post-AMI event, most studies available in literature are single-centre experiences with small numbers of patients. The current study was designed to specifically gather a robust patient cohort through a multicentre study, evaluate the trend of in-hospital outcome along a 19-year period and identify possible prognostic factors of early mortality in patients who underwent surgical treatment for post-infarction PMR.

MATERIALS AND METHODS

Ethical statement

The study was conducted in accordance with the guidelines of the Declaration of Helsinki, and the related protocol after being approved by the core centre (Maastricht University Medical Center, ID: METC 2018–0924) was authorized by the local ethical committees of each involved centre. Patients' informed consent was waived.

Patient population and study design

The patients were retrieved from the database of the CAUTION study ('Mechanical Complications of Acute myocardial Infarction: an International Multicentre Cohort Study'). The CAUTION study (trial registration: Clinicaltrials.gov, NCT03848429) is a retrospective, international, multicentre, observational trial aimed at evaluating the postoperative outcomes of patients surgically treated for post-AMI MC. The cohort consisted of 214 patients (aged >18 years) who underwent cardiac surgery for severe mitral valve (MV) regurgitation caused by post-AMI PMR between January 2001 and December 2019 at 18 different centres. A unified patient dataset was used to collect pertinent information, clinical history and assessment data from medical records.

Definitions and end points

Cardiogenic shock was defined as persistent hypotension (systolic blood pressure <90 mmHg) with reduction in cardiac index (<1.8 l/min/m^2) despite maximal conservative treatment. Urgent surgery was defined as surgery required during the same hospitalization for patients who have not been admitted in elective regimen. Emergent surgery was considered an operation that occurred within 24 h after admission, whereas salvage surgery when patients required cardiopulmonary resuscitation *en route* to the operating room. Rupture of the whole PM (body) was defined as 'complete' or 'total'; a rupture involving one of the heads of the PM was considered 'partial' or 'incomplete'. Predictive risk of in-hospital mortality after major cardiac surgery was evaluated according to European System for Cardiac Operative Risk Evaluation II and Society of Thoracic Surgeon score.

The primary end point of this study was in-hospital mortality, defined as death from any cause occurring during the same hospitalization related to the operation. The secondary end point was identification of prognostic factors for early mortality after MV surgery for post-AMI PMR.

We also assessed the temporal changes in in-hospital mortality over the study period; for this evaluation, 2 time frames (2001–2010 and 2011–2019) were used and outcome differences in terms of mortality rate compared.

Statistical analysis

Continuous variables are reported as means with standard deviation (SD) for normally distributed, or as median with interquartile range for non-normally distributed variables. Normality of distribution was assessed with the Shapiro–Wilk test. Categorical variables are reported as frequency (numbers) and percentage. Comparisons between groups (survivors to hospital discharge versus patients dead in-hospital) for univariable analysis of in-hospital mortality were performed using the Student's *t*-test or Mann–Whitney *U*-test for continuous variables and the Chi-squared or Fisher's exact test for categorical variables, as appropriate. Subsequently, variables that achieved a *P*-value of <0.2 in the univariable analysis, or thought to be clinically predictive of the outcome, and having <10% of missing data, were tested for multicollinearity and then entered into a backward stepwise multivariable logistic regression model to identify independent predictors of in-hospital mortality. Variables were retained in the model if the adjusted *P*-value was <0.1. Internal validation of predictors generated by multivariable logistic regression was assessed with bootstrapping. The above analyses were performed using the software package SPSS 26.0 for Windows (IBM, Chicago, USA). A *P*-value of <0.05 was considered statistically significant.

RESULTS

Baseline characteristics

Patients' baseline characteristics are presented in Table 1. Two-third of patients were male; the mean age was 66.9 (SD: 10.5) years. Common cardiovascular risk factors were hypertension, smoking and dyslipidaemia. PMR occurred after ST-elevation myocardial infarction (STEMI) in more than two-third of the subjects, while the one-third experience a non-STEMI; AMI location was predominantly inferior or posterior. Preoperative left ventricular systolic dysfunction was present in almost half of the individuals. Coronary angiography was performed in 88.3% of patients, with multivessel coronary artery disease (CAD) diagnosed in almost half of cases. Less than 20% of the subjects underwent PCI before the surgery. Most patients were in cardiogenic shock at presentation, and the majority of the patient cohort (60%) had intra-aortic balloon pump placed preoperatively. Extracorporeal membrane oxygenation (ECMO) support was used as a bridge to surgery in <5% of cases. Surgical status was emergent or salvage in most cases (64.5%); only <10% of subjects underwent surgery >7 days from AMI. All included patients showed a high operative risk, with a mean European System for Cardiac Operative Risk Evaluation II of 18.2% and Society of Thoracic Surgeon score of 15.1%.

Perioperative data

The PMR was complete in the majority of patients, and the posteromedial PM rupture was the most commonly finding.

Table 1: Baseline and operative characteristics

Variables	Patients ($n = 214$)
Age (years)	66.9 (10.5)
Gender (male)	156 (72.9)
BMI (kg/m^2)	26.3 (3.9)
Hypertension	132 (61.7)
Dyslipidaemia	78 (36.4)
Diabetes mellitus	48 (22.4)
Previous stroke/TIA	18 (8.4)
Smoker	89 (41.6)
COPD	46 (21.5)
CKD	40 (18.7)
PVD	40 (18.7)
Atrial fibrillation	47 (22)
STEMI	146 (68.2)
LVEF < 45%	103 (48.1)
Dyspnoea	115 (53.7)
Acute pulmonary oedema	95 (44.4)
Hemodynamic at presentation	
Cardiogenic shock	119 (55.6)
Cardiac arrest	19 (8.9)
Inotropes	154 (72)
Cardiac tamponade	5 (2.3)
Preoperative IABP	128 (59.8)
Preoperative ECMO	10 (4.7)
Preoperative PCI	35 (16.4)
Surgical status	
Urgent	65 (30.4)
Emergent/salvage	138 (64.5)
PMR site[a]	
Anterolateral	55 (28.1)
Posteromedial	141 (71.9)
PM type of rupture	
Partial	70 (32.7)
Complete	144 (67.3)
Operation technique	
MVR	177 (82.7)
MVr	37 (17.3)
CPB time (min)	127 [104–162]
Cross-clamp time (min)	79 [62–103]
Additional CABG	122 (57)
Concomitant FWR/VSR	32 (15)

Data are shown as mean (standard deviation), or median [interquartile range] or number (%), as appropriate.
BMI: body mass index; CABG: coronary artery bypass grafting; CKD: chronic kidney disease; COPD: chronic obstructive pulmonary disease; CPB: cardiopulmonary bypass; ECMO: extracorporeal membrane oxygenation; FWR: free-wall rupture; IABP: intra-aortic balloon pump; LVEF: left ventricular ejection fraction; MVR: mitral valve replacement; MVr: mitral valve repair; PCI: percutaneous coronary intervention; PMR: papillary muscle rupture; PVD: peripheral vascular disease; STEMI: ST-elevation myocardial infarction; TIA: transient ischaemic attack; VSR: ventricular septal rupture.
[a]Data available in 196 patients (91.6%).

Thirty-two subjects (15%) presented with concomitant ventricular free-wall rupture or ventricular septal rupture requiring surgical repair. Most patients underwent MV replacement (MVR). Valve replacement was performed with mitral bioprosthesis implantation in 58.4%, while mechanical valve prostheses was used in 41.6%.

MV repair (MVr) performed in <20% of cases (Table 1). In our series, 4 patients with complete PMR underwent MVr. Slightly >50% of patients had associated coronary artery bypass grafting (CABG) at the time of MV surgery. Postoperatively, mechanical circulatory supports (MCS), including intra-aortic balloon pump and ECMO, were adopted in a minority of patients (13.1% and 6.1%, respectively) (Table 2).

Table 2: Postoperative data and outcomes

Variables	Patients ($n = 214$)
ICU stay (days)	9.8 (9)
Postoperative inotropes	142 (66.4)
Postoperative IABP	28 (13.1)
Postoperative ECMO	13 (6.1)
Hospital stay (days)	20.8 (15)
On-table death	9 (4.2)
In-hospital mortality	53 (24.8)
Postoperative complications	
LCOS	35 (16.4)
Right ventricular failure	18 (8.41)
Atrial fibrillation	31 (14.5)
Sepsis	22 (10.3)
Pneumonia	25 (11.7)
ARDS	23 (10.8)
AKI	55 (25.7)
Dialysis	17 (7.9)
Cerebrovascular accident	18 (8.4)
Rexploration for bleeding	21 (10.2)
Causes of operative death[a]	
No CPB weaning	5 (9.4)
Incontrollable bleeding	4 (7.5)
LCOS	18 (34)
MOF	5 (9.4)
Sepsis	4 (7.5)
Stroke	1 (1.9)
AKI	6 (11.3)
Bowel infarction	1 (1.9)
Pneumonia/ARDS	4 (7.5)
AMI	3 (5.7)
Unknown	2 (3.8)

Data are shown as mean (standard deviation) or *n* (%) as appropriate.
AKI: acute kidney injury; AMI: acute myocardial infarction; ARDS: acute respiratory distress syndrome; CPB: cardiopulmonary bypass; ECMO: extracorporeal membrane oxygenation; IABP: intra-aortic balloon pump; ICU: intensive care unit; LCOS: low cardiac output syndrome; MOF: multiorgan failure; n: number.
[a]n/N ($N = 53$).

Postoperative outcomes

Early postoperative outcomes are shown in Table 2. Postoperative complications were common, including acute kidney injury, as the most common major adverse event, followed by postoperative atrial fibrillation, low cardiac output syndrome (LCOS) and pneumonia. Re-thoracotomy for bleeding was required in almost 10% of cases. The mean intensive care unit and hospital length of stay were 9.8 (SD: 9) and 20.8 (SD: 15) days, respectively.

In-hospital mortality was 24.8% ($n = 53$), with 9 intraoperative deaths, either due to ventricular failure precluding CPB weaning or due to uncontrolled bleeding. LCOS followed by acute kidney injury and multiorgan failure were by far the most common causes of early mortality. Temporal trend analysis revealed no substantial changes over time in the in-hospital mortality rate: 23.8% (time frame: 2001–2010) vs 25.7% (time frame: 2011–2019) ($P = 0.75$) (Fig. 1).

Multivariable analysis identified preoperative chronic kidney disfunction [odds ratio (OR): 2.62, 95% confidence interval (CI): 1.07–6.45, $P = 0.036$], cardiac arrest (OR: 3.99, 95% CI: 1.02–15.61, $P = 0.046$) and CPB duration (OR: 1.01, 95% CI: 1.00–1.02, $P = 0.04$) as independent predictors of in-hospital mortality.

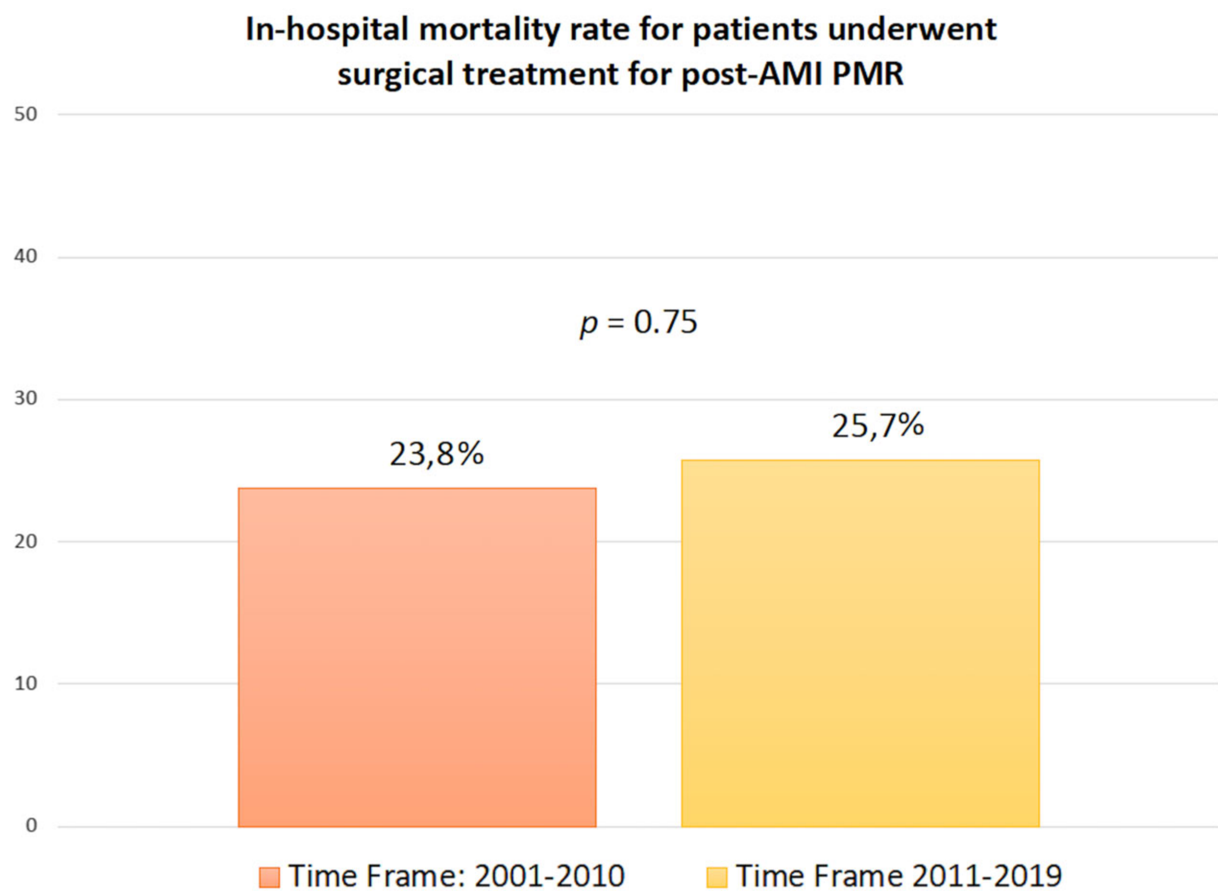


Figure 1: Major time frames used to examine temporal trends in the in-hospital mortality rate.

Interestingly, PMR site and type and MV surgical technique did not impact odds of early mortality. Multivariable analysis also demonstrated that concomitant CABG during MV surgery was associated with improved survival (OR: 0.38, 95% CI: 0.16–0.92, $P = 0.031$) (Supplementary Material, Table S1). Internal validation with bootstrapping demonstrated good performance of the model.

DISCUSSION

In the $CAUTION_{PMR}$ study, we analysed the in-hospital mortality and complications of patients submitted to surgical treatment for post-infarction PMR in 18 centres worldwide over a period of almost 2 decades. The study main findings were as follows: (i) the overall in-hospital mortality rate was 24.8%; (ii) concomitant CABG during MV surgery was an independent predictor of early survival; (iii) type of rupture (complete versus partial), PMR site (posteromedial versus anterolateral) and surgical technique (MVR versus MVr) had not significantly impact on early mortality; and (iv) in-hospital mortality rate remained substantially unchanged throughout the study period.

Severe acute mitral regurgitation due to post-AMI PMR represents a potentially fatal condition, if not treated promptly [3]. Despite the lack of supporting data from randomized trials, many retrospective studies have shown that in-hospital mortality in this setting is remarkably lower with expeditious surgical treatment as compared to medical therapy alone [3, 5]. In the past years, few single-centre studies or, more recently, national registries, reported comprehensive information on post-AMI PMR [6–11]. To the best of our knowledge, this is the first multicentre international study focusing on the clinical characteristics and in-hospital outcomes of surgically treated PMR. Mean age and male predominance in the current analysis were similar to those reported in literature [11]. Apart from hypertension, present in >60% of the patients, other well-known cardiovascular risk factors were identified in less than half of cases, with rates comparable to those previously described [9]. However, in this report, comorbidities were not predictive of in-hospital mortality with the exception of CKD, differently from other recent publications [9, 10].

Posteromedial PMR has been reported to be far more common than anterolateral PMR and the $CAUTION_{PMR}$ findings confirms these data [9, 12]. The reason for such uneven predominance of posteromedial PMR is related to the different coronary supplies: indeed, while anterolateral PM is supplied by branches of both the left anterior descending and the left circumflex coronary arteries, posteromedial PM received blood from either the left circumflex or the right coronary artery through the posterior descending artery [13]. Therefore, posteromedial PM is more susceptible to the ischaemic insult, in case of coronary obstruction. Moreover, in our cohort, the incidence of inferior or posterior AMI was almost double that of anterolateral one. Despite these anatomical and physiological differences, in this analysis, PMR site was not associated with the in-hospital mortality, differently from what Figueras *et al.* [14] observed in a small series of patients (higher mortality in anterolateral PMR).

As well known, PMR may present with complete or partial PMR. Interestingly, while partial rupture was generally reported to occur slightly more frequently than complete rupture [6, 7]; in our cohort, the latter was observed twice more frequently than partial rupture. Despite most reports described a worse outcome for patients developing complete PMR, probably because of its higher association with tissue fragility and haemodynamic instability [6, 7, 15], we found no significant difference for in-hospital mortality according to the type of rupture. Such a finding, however, may be explained by the small number of subjects who developed partial PMR following AMI in this study. Besides, data about the type and site of rupture were lacking in the most recent national registries [10, 11].

PMR occurrence is usually accompanied by a new mitral regurgitation murmur and, more importantly, is often shortly followed by acute pulmonary oedema and haemodynamic instability, ultimately leading to cardiogenic shock, or even cardiac arrest [2, 16]. Due to the abrupt and severe impact of PMR on patients' clinical conditions, unsurprisingly, we observed a higher mortality rate among patients presenting with cardiac arrest and with severe left ventricular dysfunction, when compared to more stable patients (47.4% vs 22.6% and 31.1% vs 18.9%, respectively), in accordance with other reports [10, 11]. Moreover, preoperative cardiac arrest was identified as an independent predictor of in-hospital death at multivariable analysis. The ESC (European Society of Cardiology) and AHA/ACC (American Heart Association/American College of Cardiology) guidelines for the management of patients with STEMI advocate the use of short-term MCS for patients with post-AMI MC presenting with cardiac arrest or developing cardiogenic shock, to achieve temporary circulatory stabilization on the way to surgery [17, 18]. In this study, there was no significant difference in early mortality between individuals with, or without preoperative MCS support, in accordance with previous reports [2, 19]. This result might be expression of the extremely compromised conditions of subjects requiring immediate haemodynamic stabilization with MCS. In our opinion, in patients presenting with post-AMI PMR and refractory cardiogenic shock, short-term MCS as a bridge to surgery should be part of the decision-making. ECMO support allows immediate circulatory support, providing time and haemodynamic stability for the necessary diagnostic workup (such as coronary angiography) and surgical intervention planning, while reversing organ damage. However, veno-arterial ECMO relies on the retrograde aortic flow to maintain end-organ perfusion; a recognized limitation of this strategy is the resultant increase in left ventricular afterload, which increases myocardial work. This is particularly deleterious in PMR, as it can worsen valvular regurgitation and pulmonary oedema. Strategies to unload the left ventricle in this situation should be, therefore, considered. Contemporary observational studies suggest that LV venting in cardiogenic shock patients supported with ECMO may be associated with haemodynamic improvement and better outcomes [20]. Given the fact that PMR often associates with multivessel CAD jeopardizing large areas of myocardium, patients are at a particularly high risk for postcardiotomy low cardiac output syndrome, especially those in which a complete coronary artery revascularization is not achieved during surgery. In the immediate postoperative period, ECMO would allow for ventricular recovery and meaningfully reduce the risk of LCOS, the most common cause of postoperative death in this subgroup of patients.

In clinical practice, it is widely accepted that, given the haemodynamic comprise and the poor prognosis associated with post-AMI PMR, early surgery represents the gold standard for treatment [1, 4, 15]. MVR still remains the treatment of choice, carried out in almost three-quarter of patients in the current report. MVR is usually reserved for patients with complete PMR, due to the necrotic and friable infarcted tissue [11]. The choice of valve prosthesis must be made according to current valve disease guidelines. Preservation of the valvular and subvalvular apparatus, whenever feasible, should be evaluated. In this subset of patients, in fact, MVr would be more complex and result in prolonged CPB and ischaemic time. Furthermore, the lack of certainty about MVr success and durability in such post-AMI PMR injury might discourage surgeons to pursue it. MVr, however, could be considered in selected cases [21, 22]. Notwithstanding, some reports suggested that MVr could improve patients' survival, as compared to MVR, but selection bias must also be taken into account [9, 23]. Our study showed no significant difference in early mortality between patients undergoing MVR and MVr. Further and dedicated analysis are required to provide additional and more consistence data, and to assess whether one surgical approach is superior over the other. The finding that prolonged CPB time was independently associated with increased odds of in-hospital mortality is not surprising and is probably a reflection of the surgical complexity of managing patients with post-infarction PMR.

In this investigation, we observed a high incidence of concomitant mechanical complication, such as ventricular free-wall rupture and ventricular septal rupture, in patients who developed PMR following AMI. However, we did not find any statistically significant difference in terms of in-hospital mortality in patients who underwent MV surgery and associated surgical procedure. We can state that, considering the small cohort of patients, the additional of a surgical procedure to MV surgery for PMR does not negatively affect early outcomes.

The impact of concomitant CABG in the setting of post-AMI MC remains unclear, although some distinctions should be made according to the type of complications [9, 11]. In the current study, concomitant CABG was found to be the only independent predictor of early survival. Although generally debated, such important result seems reasonable from several points of view. First of all, it should be borne in mind that PMR, being a complication of AMI, represents an epiphenomenon of CAD, that itself needs to be addressed effectively, also to reduce the possible risk of further ischaemic episodes. Indeed, additional CABG during MV surgery for PMR has shown, in some reports, an important role in improving LV function and both early and long-term survival [15, 24]. Moreover, it is noteworthy that not all patients could undergo preoperative coronary angiography due to the severe haemodynamic instability demanding emergent procedure, concomitant CABG still appeared to improve patients' outcome. Finally, although common drawbacks described for CABG in this context include the need to prolong CPB time and a higher procedural risk, it should also be underlined that, from the surgical point of view, performing concomitant revascularization associated with an MV procedure is technically less demanding than in the setting of surgical repair of FWR or ventricular septal rupture. In fact, in these settings, the coronary arteries responsible for the ventricular wall infarction are usually entrapped in the closing suture, therefore making CABG technically not feasible [6, 7, 25]. This might also partially explain such significant finding in PMR, differently from the other post-AMI MC [25]. Based on these assumptions, we believe that concomitant CABG should be performed whenever possible in these patients, to possibly improve survival.

The in-hospital mortality observed in our series was 1 patient over 4 treated, ratio in accordance with data reported in literature (range from 20% to 40%) [2, 3, 9–11, 19]. Although quite high, such results can be reasonably explained by the severe condition represented by post-infarction PMR. It is noteworthy that almost 15% of deaths occurred intraoperatively, thereby, suggesting the need of improved management protocols for these patients. Furthermore, more than half of patients died peri-operatively due to LCOS or multiorgan failure. In addition, over the study period, there were no substantial changes in early mortality. Indeed, the 2 major time frames used to examine temporal trends in the in-hospital mortality rate indicated no considerable changes over the study years. A similar finding was described by Lorusso *et al.* [16] investigating the in-hospital outcome of patients undergoing emergency surgery for mitral pathologies, showing that in-hospital mortality occurred in a quarter of the treated patients and lack of improvement in a 20-year study period. These results have been shown in other post-AMI mechanical complication [26]. The lack of a significant improvement in the in-hospital survival of patients surgically treated for post-AMI mechanical complications most likely indicates the need for more aggressive and optimal peri-operative management strategies in those individuals. Further efforts should be directed towards improving therapeutic measurers for the subgroup of patients that are at higher risk for worse outcome. This entails improving patients' awareness of symptoms and the importance of early presentation as well as improving risk stratification and treatment strategies. Given the limited use of MCS, such as ECMO, an extended and more aggressive adoption of MCS, also prophylactically, should be considered in this subgroup of patients and thoroughly investigated to indicate whether this might be the way to improve in-hospital survival in these critical subjects.

Limitations

We acknowledge several important limitations in this study. First, due to its retrospective nature, both selection bias and uncontrolled confounders cannot be excluded. Second, the multicentre design required a data collection form with a limited number of variables to avoid missing data; thus, the possibility that non-reported variables could have influenced the results of the analysis cannot be ruled out. For example, the database has no information on: the interval from PMR to intervention, the technique used for MVr, the infarcted-related artery (culprit lesion of AMI), the number grafts performed, the revascularized vessel territories by PCI or CABG and the conduits used for CABG. Third, the relative small sample size underpowered the statistical analysis and could have limited the number of statistically significant variable; indeed, some risk factors associated with an increased risk of mortality shown in a report from a large national registry (e.g. older age, MVR, cardiogenic shock) [11] were not statistically signification in our analysis. Furthermore, this study is limited to the operative outcomes and it does not provide information on late outcomes. Finally, data concerning other PMR patients managed conservatively or who died without surgery in all participating centres are lacking, making a comprehensive analysis of the actual prevalence of such a disease not feasible.

CONCLUSIONS

MV surgery for post-AMI PMR is associated with high in-hospital mortality (∼25%), with no substantial changes over the last 20 years. The findings of the present multicentre study seem to indicate that the type or site of rupture, as well as surgical technique, do not influence early patients' survival. Concomitant CABG during MV surgery for post-AMI PMR appears protective against early mortality, and therefore, additional surgical revascularization should be considered whenever possible in this group of patients. Finally, by analysing the timing and mode of death, a more aggressive MCS application in the perioperative phase to counteract LCOS should be explored.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

Conflict of interest: Roberto Lorusso is a consultant for Medtronic and LivaNova and a member of the Advisory Board of Eurosets and PulseCath.

Data Availability Statement

All relevant data are within the manuscript and its Supporting Information files.

Author contributions

Giulio Massimi: Conceptualization; Data curation; Formal analysis; Investigation; Supervision; Writing—original draft. **Daniele Ronco:** Data curation; Formal analysis; Investigation; Supervision. **Michele De Bonis:** Conceptualization; Supervision; Writing—review & editing. **Mariusz Kowalewski:** Formal analysis; Software; Supervision; Writing—review & editing. **Francesco Formica:** Data curation; Supervision. **Claudio Francesco Russo:** Supervision. **Sandro Sponga:** Data curation; Supervision. **Igor Vendramin:** Data curation; Supervision. **Giosuè Falcetta:** Data curation; Supervision. **Theodor Fischlein:** Data curation; Supervision. **Giovanni Troise:** Data curation; Supervision. **Cinzia Trumello:** Data curation; Supervision. **Guglielmo Actis Dato:** Data curation; Supervision. **Massimiliano Carrozzini:** Data curation; Supervision. **Shabir Hussain Shah:** Data curation; Supervision. **Valeria Lo Coco:** Data curation; Visualization. Emmanuel Villa: Data curation; Validation. **Roberto Scrofani:** Data curation; Supervision. **Federica Torchio:** Data curation. **Carlo Antona:** Data curation; Supervision. **Jurij Matija Kalisnik:** Data curation; Supervision. **Stefano D'Alessandro:** Data curation; Supervision. **Matteo Pettinari:** Data curation; Supervision. **Peyman Sardari Nia:** Data curation; Supervision; Validation; Writing—review & editing. **Vittoria Lodo:** Data curation. **Andrea Colli:** Data curation; Supervision. **Arjang Ruhparwar:** Supervision. **Matthias Thielmann:** Data curation; Supervision; Validation. **Bart Meyns:** Data curation; Validation. **Fareed A. Khouqeer:** Data curation; Supervision. **Carlo Fino:** Data curation; Supervision. **Caterina Simon:** Data curation. **Adam Kowalowka:** Data curation. **Marek A. Deja:** Data curation. **Cesare Beghi:** Conceptualization; Methodology; Supervision; Writing—review & editing. **Matteo Matteucci:** Conceptualization; Data curation; Supervision; Visualization; Writing—review & editing. **Roberto Lorusso:** Conceptualization; Methodology; Supervision; Validation; Visualization; Writing—review & editing.

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