





Surgical outcomes of post-infarct ventricular septal defect repair: Insights from the UK national adult cardiac surgery audit database

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Abstract

Objectives: Ventricular septal defect (VSD) is becoming a progressively less frequent mechanical complication of myocardial infarction (MI). However, this event is still associated with high operative mortality. We aimed to describe the trends and the risk factors associated with surgical VSD repair outcomes and to provide a clinical benchmark for percutaneous VSD closure strategies.

Methods: Using the UK National Adult Cardiac Surgery Audit database, we identified 1010 patients undergoing surgical VSD repair from 1996 to 2018. The primary outcome was operative mortality. Mixed-model, multivariable logistic regression was used to identify the risk factors associated with operative mortality taking into account the variation related to the centre, the surgeon and the year of the operation.

Results: Both the number of surgical VSD repair and the mortality rate did not change significantly over the 23-year timeframe. Operative mortality was 38.9% overall and was higher when patients were operated within the first 6 h (75%) or the first 24 h (61.3%) from the index MI. Risk factors associated with higher odds of mortality were early surgery, older age, cardiogenic shock, renal failure, previous percutaneous coronary intervention and urgent/emergent operations. Moreover, the mortality rate was similar among patients undergoing isolated VSD repair and VSD repaired combined with surgical coronary revascularization alone or with concomitant mitral valve procedures.

Conclusions: Post MI VSD remains a dreaded mechanical complication characterized by high surgical operative mortality. A delayed operation, whenever possible, appears to be the most beneficial strategy to reduce mortality.

KEYWORDS

myocardial infarction, national database, operative mortality, ventricular septal defect

Abbreviations: CABG, coronary artery bypass grafting; IABP, intra-aortic balloon pump; MI, myocardial infarction; PCI, percutaneous coronary intervention; VSD, ventricular septal defect.

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1 | INTRODUCTION

Ventricular septal defect (VSD) due to ischemic septal rupture represents a rare event complicating ST-elevation myocardial infarction (MI). There has been a significant decrease in the incidence of this dreaded complication, from 1% to 3% in the prethrombolysis eras to 0.2%–0.34% in the latest years.¹ However, this event is still associated with very poor clinical outcomes. The mortality rate is as high as 94% after medical treatment whereas surgical repair of VSD has been reported to have an operative mortality higher than 30% and it varies largely according to the timing of surgery. Currently, there is no consensus on which is the optimal timing for the repair of VSD as patients undergoing surgery early after the MI show worse outcomes while patients in which surgical repair is attempted after 2–3 weeks after the culprit MI have the lowest operative mortality.^{2,3}

More recently, the use of percutaneous devices to close the septal defect has emerged as a potential alternative to surgical repair. Although interventional VSD closure is associated with a more rapid correction of the interventricular shunt, it still remains impacted by high mortality and morbidity and therefore, surgical repair remains in the majority of cases the gold standard for these patients.⁴

This study aimed to provide a clinical benchmark for the treatment of post-MI VSD by reporting on the outcomes of VSD repair over a 23-year period and identify risk factors associated with worse short-term outcomes after surgical repair.

2 | METHODS

The study is part of a research project approved by the Health Research Authority (HRA) and Health and Care Research Wales. Patient consent was waived (HCRW) (IRAS ID: 278171) in accordance with the research guidance. This study complies with the Declaration of Helsinki.

2.1 | National adult cardiac surgery audit (NACSA) dataset

A complete extract of prospectively collected data from the NACSA was obtained from the National Institute of Cardiovascular Outcomes Research (NICOR) central cardiac database and retrospectively analyzed. The definitions of the database variables used for this study are available at <https://www.nicor.org.uk/national-cardiac-audit-programme/adult-cardiac-surgery-surgery-audit/>. The NICOR registry prospectively collects demographic, as well as pre- and postoperative clinical information, including mortality, for all major adult cardiac surgery procedures performed in the UK. The flow of the data from surgeon-input to analysis has been described elsewhere.⁵ Missing data are resolved during the validation stages of the data transfer from individual centers. Missing and conflicting data for in-hospital mortality status are backfilled and validated via record linkage to the Office for National Statistics census database. The overall percentage of missing data for baseline information is very low (1.7%). Missing categorical or dichotomous variable data were

imputed with the mode while missing continuous variables data imputed with the median. For the present analysis, from the NACSA registry we identified patients undergoing surgical repair for post-MI VSD from January 1996 to December 2018 in England, Scotland and Wales. Information on the anatomical position of the defect (anterior vs. posterior) was not available in the dataset.

2.2 | Outcomes

The primary outcome was in-hospital mortality. Secondary outcomes investigated were postoperative cerebrovascular events, need for postoperative dialysis, deep sternal wound infection, reexploration for bleeding, insertion of intra-aortic balloon pump (IABP) or ventricular assist devices and length of stay.

2.3 | Statistical analysis

Categorical variables are presented as count and proportion and were compared using the Pearson's Chi-squared test or Fisher's exact test, as appropriate, whereas continuous variables were reported as median and interquartile range and were compared using Wilcoxon rank sum test.

Patients characteristics were reported in the overall sample and were stratified by patient status at discharge (survivor vs. non-survivors). Predictors of operative mortality were investigated using a multivariable, generalized linear mixed model, which included the patient characteristics found significant at the univariable analysis as fixed effect covariates. A clustering effect was anticipated for patients operated in the same hospital or by the same surgeon and therefore these two variables were included in the model as random intercepts. As surgical outcomes may have improved in the last decade, year of surgery was also included as random intercept. Effect estimates for fixed effect covariates were reported as odds ratio (OR) and 95% confidence interval (CI). The marginal R-squared considers only the variance of the fixed effects, while the conditional R-squared takes both the fixed and random effects into account.⁶

The primary outcome was also investigated according to the time interval from MI to the surgery, and according to the procedure performed (isolated VSD repair, concomitant CABG or CABG plus mitral valve surgery).

p value <.05 was considered significant in all the analysis. Statistical analysis was performed using R version 4.0.0 using the packages sjplot, lme4, lmerTest, gtsummary.

3 | RESULTS

From 1996 to 2018, 1010 patients underwent surgical repair of post-MI VSD in 42 centres by 370 surgeons. Over the 23-year period, the number of VSD undergoing surgical repair remained stable after an initial upsurge in the first 5 years (Figure 1) and ranged from 41 to 67 cases per year. The overall median number of VSD repairs per surgeon was 2 (1–3) and

the overall median hospital volume 24 (13–36). On average, each centre operated 3 (2–4) patients each year and each surgeon operated on 1 (1–2) patients annually.

Patient characteristics are presented in Table 1. The median age was 70 (62–75 years) and most of the patients were men (66%). Surgical repair of VSD was mainly performed in the timespan of 1–30 days after the culprit MI (69%), whereas the least patients were operated on within the first 6 h after the MI (2.4%). Half of the patients had a critical preoperative state presenting with cardiogenic shock (54%) and/or inotropic support (41%). A total of 252 (25%) patients had a previous percutaneous coronary intervention (PCI). Repair of the post-MI VSD was urgent or emergent in 88% of the cases. The median interval time from hospital admission to surgery was 1 (0–5) day.

The median cardiopulmonary bypass time was 135 (104, 171 min) and the median cross-clamp time 88 (62–116 min) (Table 2). Fifty-four percent of patients underwent concomitant surgical revascularization, with a median number of grafts of 2 (1–2), and 2.5% underwent concomitant mitral valve procedures (Table 2).

The overall operative mortality was 38.9% ($n = 393$) (Table 3). Patients who died were more likely to be older, have an impaired left ventricular and renal function, and present with unstable angina. Also, nonsurvivors tended to have undergone a previous PCI and be more critically ill presenting with cardiogenic shock, inotropic support and preoperative ventilation. VSD repair was more likely to be nonelective and take place within the first 24 h after MI in patients who died (Table 1). Over the years, the operative mortality ranged from 27.8% to 48.8% and

did not change significantly (Figure 2). When the primary outcome was analysed according to the interval between MI and the surgical repair, the operative mortality was significantly higher in patients undergoing surgery within the first 24 h (75% and 61.3% if operated within 6 h or between 6 and 24 h, respectively) compared to patients with a delayed repair (Figure 3). Moreover, operative mortality did not differ significantly when isolated VSD repair was compared to VSD repaired with concomitant CABG and mitral valve surgery (Figure 4).

Patients presenting with deteriorated clinical conditions (e.g., cardiogenic shock) had a double rate of operative mortality compared to patients with stable hemodynamic (50.0% vs. 26.1%; $p < .001$). Among patients with cardiogenic shock, 125 (23%) received preoperative IABP, 36 also had an Impeller implanted and 1 a ventricular assist device. The operative mortality of patients with cardiogenic shock and supported by mechanical devices was not significantly different from the mortality of patients without mechanical support (49.6% vs. 50.1%; $p = 1.0$).

The multivariable regression model confirmed the trend towards a lower risk of operative mortality with delayed surgery, in particular surgical repair of VSD between 1 and 30 days after MI had an OR of 0.35 (95% CI: 0.12–0.99) and after 30 days the OR was 0.25 (95% CI: 0.08–0.80). Other risk factors associated with a worst mortality were older age, cardiogenic shock, renal failure and urgent or emergent operations (Table 4). PCI performed within 24 h of the index surgery was associated with a more than twofold higher odds of operative mortality (Table 4).

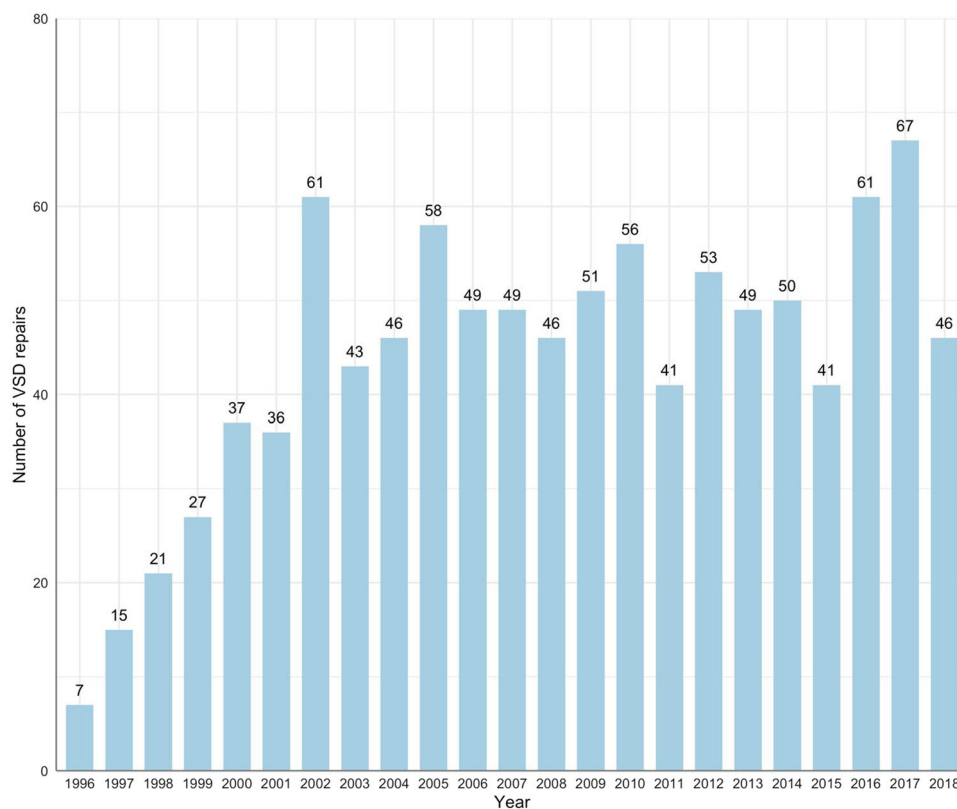


FIGURE 1 Number of postmyocardial infarction ventricular septal defect (VSD) surgically repaired over time

TABLE 1 Baseline characteristics of patients undergoing surgical repair of postmyocardial infarction ventricular septal defect in the overall cohort and between survivors and nonsurvivors

Characteristic	Overall, N = 1010 ^a	Survivors, N = 617 ^a	Nonsurvivors, N = 393 ^a	p value ^b
Age (years)	70 (62, 75)	68 (61, 74)	71 (64, 76)	.002
Index of multiple deprivation	18 (10, 31)	18 (10, 32)	18 (10, 31)	.8
Female sex	345 (34%)	207 (34%)	138 (35%)	.6
CCS Class 3 or 4	546 (54%)	300 (49%)	246 (63%)	<.001
NYHA Class 3 or 4	771 (76%)	471 (76%)	300 (76%)	>.9
Interval between MI and surgical repair				<.001
<6 h	24 (2.4%)	6 (1.0%)	18 (4.6%)	
6–24 h	155 (15%)	60 (9.7%)	95 (24%)	
1–30 days	695 (69%)	436 (71%)	259 (66%)	
≥31 days	136 (13%)	115 (19%)	21 (5.3%)	
PCI				<.001
No	758 (75%)	487 (79%)	271 (69%)	
<24 h, same index admission	80 (7.9%)	23 (3.7%)	57 (15%)	
>24 h, same index admission	130 (13%)	75 (12%)	55 (14%)	
>24 h, previous admission	42 (4.2%)	32 (5.2%)	10 (2.5%)	
Previous heart surgery	45 (4.5%)	32 (5.2%)	13 (3.3%)	.2
Diabetes	137 (14%)	76 (12%)	61 (16%)	.15
Hypertension	511 (51%)	304 (49%)	207 (53%)	.3
Smoking				.5
Never smoker	342 (34%)	201 (33%)	141 (36%)	
Former smoker	418 (41%)	259 (42%)	159 (40%)	
Current smoker	250 (25%)	157 (25%)	93 (24%)	
COPD	130 (13%)	75 (12%)	55 (14%)	.4
Previous cerebrovascular accidents				.3
TIA	22 (2.2%)	14 (2.3%)	8 (2.0%)	
CVA with recovery	14 (1.4%)	7 (1.1%)	7 (1.8%)	
CVA with deficit	9 (0.9%)	8 (1.3%)	1 (0.3%)	
PVD	72 (7.1%)	45 (7.3%)	27 (6.9%)	.8
Preoperative AF	54 (5.3%)	31 (5.0%)	23 (5.9%)	.6
Preoperative VF	15 (1.5%)	9 (1.5%)	6 (1.5%)	>.9
3-vessel coronary artery disease	234 (23%)	141 (23%)	93 (24%)	.8
LVEF				<.001
<30%	356 (35%)	187 (30%)	169 (43%)	
30%–50%	456 (45%)	318 (52%)	138 (35%)	
≥50%	198 (20%)	112 (18%)	86 (22%)	
Cardiogenic shock	542 (54%)	271 (44%)	271 (69%)	<.001
Inotropic support	414 (41%)	211 (34%)	203 (52%)	<.001
UA	556 (55%)	313 (51%)	243 (62%)	<.001

TABLE 1 (Continued)

Characteristic	Overall, N = 1010 ^a	Survivors, N = 617 ^a	Nonsurvivors, N = 393 ^a	p value ^b
Preoperative ventilation	90 (8.9%)	40 (6.5%)	50 (13%)	<.001
Urgency				<.001
Elective	31 (3.1%)	29 (4.7%)	2 (0.5%)	
Urgent	333 (33%)	271 (44%)	62 (16%)	
Emergency	551 (55%)	283 (46%)	268 (68%)	
Salvage	95 (9.4%)	34 (5.5%)	61 (16%)	
BMI	26.0 (23.7, 28.4)	26.0 (23.7, 28.4)	26.0 (23.8, 28.7)	0.3
CKD	181 (18%)	81 (13%)	100 (25%)	<.001
Days from admission to surgery	1 (0, 5)	2 (1, 8)	1 (0, 2)	<.001

Abbreviations: AF, atrial fibrillation; BMI, body mass index; CCS, Canadian Cardiovascular Society; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accidents; LVEF, left ventricular ejection fraction; MI, myocardial infarction; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; PVD, peripheral vessel disease; TIA, transient ischemic attack; UA, unstable angina; VF, ventricular fibrillation.

^aMedian (IQR); n (%).

^bWilcoxon rank sum test; Pearson's Chi-squared test; Fisher's exact test.

TABLE 2 Operative characteristics in the overall cohort and according to the operative mortality outcome

Characteristic	Overall, N = 1010 ^a	Survivors, N = 617 ^a	Nonsurvivors, N = 393 ^a	p value ^b
Cardiopulmonary bypass time (min)	135 (104, 171)	128 (97, 162)	146 (115, 201)	<0.001
Cross-clamp time (min)	88 (62, 116)	83 (60, 112)	90 (64, 130)	<0.001
Concomitant CABG	543 (54%)	334 (54%)	209 (53%)	0.8
Concomitant MVP	25 (2.5%)	15 (2.4%)	10 (2.5%)	0.9
Number of grafts	1 (1-2)	1 (1-2)	1 (1-2)	0.4

Abbreviations: CABG, coronary artery bypass grafting; IQR, interquartile range; MVP, mitral valve procedures.

^aMedian (IQR); n (%).

^bWilcoxon rank sum test; Pearson's Chi-squared test; Fisher's exact test.

The incidence of secondary outcomes is presented in Table 3. The most common postoperative complication was postoperative dialysis, reported in 244 (24%) patients, followed by insertion of IABP required in 159 (16%) patients.

4 | DISCUSSION

This study is one of the largest reported cohort of VSD surgical repair and the first from the national United Kingdom database over a 23-year period.

We found that the number of VSD surgical repairs did not change over this long period of time suggesting that the introduction and wider adoption of interventional strategies for the closure of VSD did not impact the overall surgical management of this dreaded event, for which we found an overall operative mortality of 38.9%. We also found that the

closer the operation to the onset of the culprit MI the worse the operative outcomes for the patients. No difference was found in the operative mortality among patients undergoing isolated VSD repair or concomitant CABG or CABG and mitral valve surgery.

Surgical repair of VSD has historically been reported to be associated with high operative mortality in previous series. In a report of 2876 patients from the Society of Thoracic Surgery database, authors found an operative mortality of 42.9%, which resulted to be the highest rate compared to any other cardiac procedures in the same database.⁷ In this cohort the proportion of patients presenting with cardiogenic shock was 51.7% and the proportion of emergency/salvage operations was 49.7%. An even higher mortality was reported in the Global Utilization of Streptokinase and TPA for Occluded Coronary Arteries (GUSTO-I) trial in which out of 41,000 patients, 84 (0.2%) developed a post-MI VSD and surgical repair was associated with better mortality compared to conservative management (47% vs. 94%).⁸ More recently, investigators

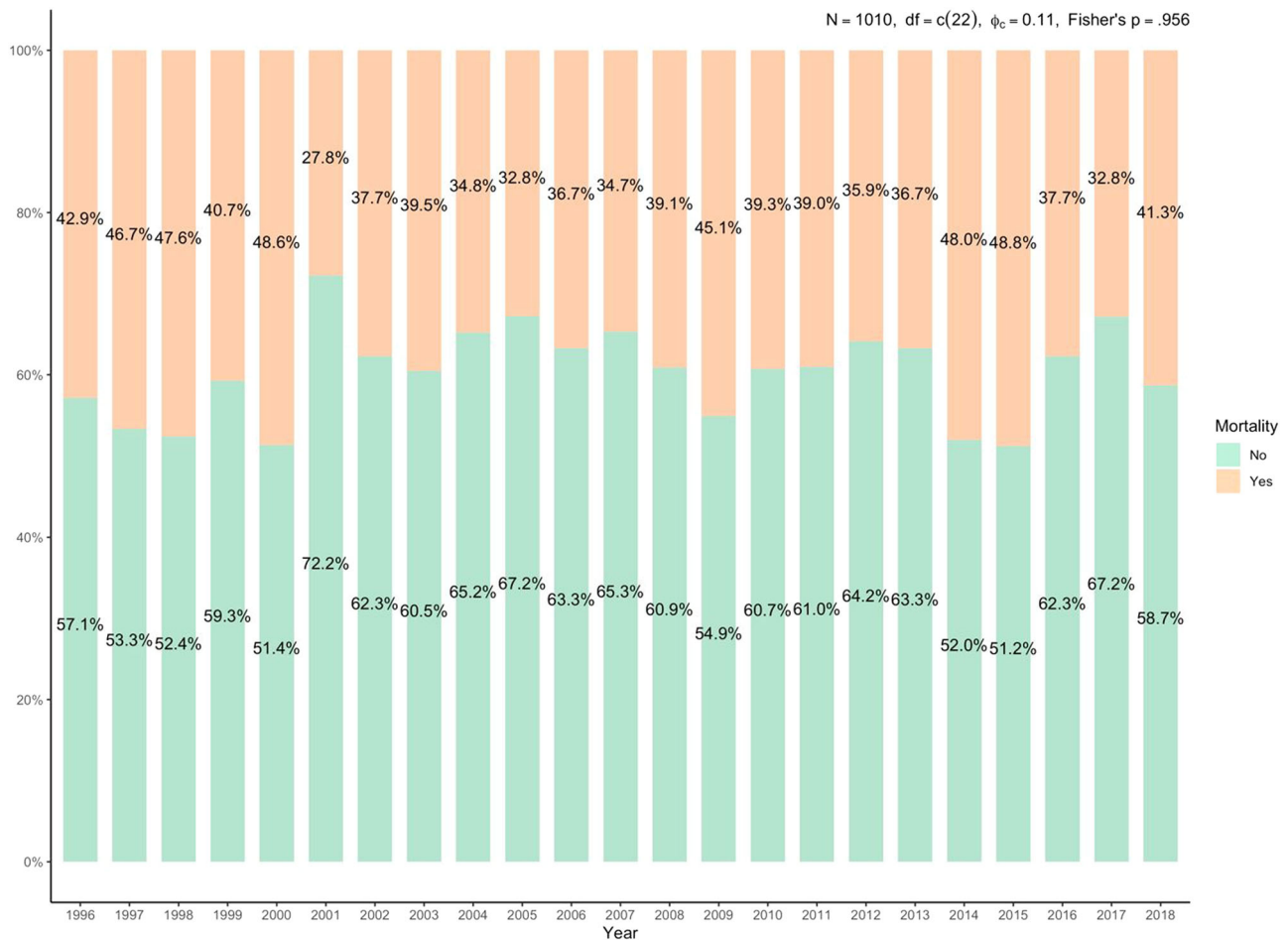
TABLE 3 In-hospital outcomes of patients undergoing surgical repair of postmyocardial infarction ventricular septal defect

Characteristic	Overall, N = 1010 ^a	Survivors, N = 617 ^a	Nonsurvivors, N = 393 ^a	p value ^b
Mortality	393 (38.9%)	0 (0)	393 (100%)	
Postoperative CVA				.2
TIA	10 (1.1%)	8 (1.5%)	2 (0.6%)	
Stroke	29 (3.3%)	14 (2.6%)	15 (4.5%)	
Postoperative dialysis	244 (28%)	84 (15%)	160 (48%)	<.001
Postoperative DSWI	3 (1.1%)	2 (1.2%)	1 (1.0%)	>.9
Postoperative IABP	159 (37%)	85 (33%)	74 (43%)	.035
Postoperative VAD	7 (1.9%)	2 (0.9%)	5 (3.3%)	.12
Length of stay, days	11 (5, 21)	15 (9, 26)	3 (1, 10)	<.001
Return to theatre due to bleeding	84 (8.3%)	43 (7.0%)	41 (10%)	.05

Abbreviations: CVA, cerebrovascular accident; DSWI, deep sternal wound infection; IABP, intra-aortic balloon pump; IQR, interquartile range; TIA, transient ischemic attack; VAD, ventricular assist device.

^an (%); Median (IQR).

^bFisher's exact test; Pearson's Chi-squared test; Wilcoxon rank sum test.

**FIGURE 2** Mortality rates over time following ventricular septal defect surgical repair

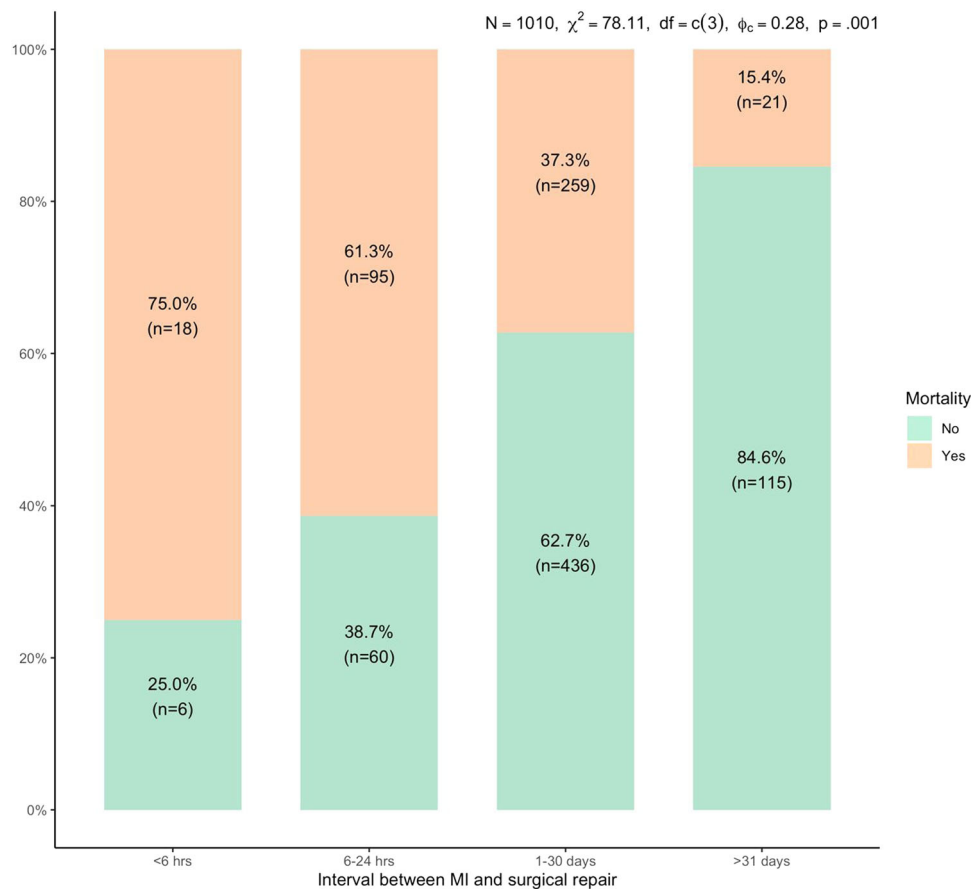


FIGURE 3 Operative mortality following ventricular septal defect surgical repair according to the interval between myocardial infarction (MI) and surgery

from the Japanese National Database reported on the outcomes of 1397 patients undergoing VSD repair achieving an operative mortality and a 30-day mortality of 24.3% and 33%, respectively.⁹ Our operative mortality is consistent with these previous reports despite our cohort had a higher proportion of patients presenting with critical preoperative status (e.g., cardiogenic shock) and undergoing urgent/emergent/salvage surgery.

Interestingly, the mortality rate did not change substantially over time despite the improvement in surgical and perioperative care. This could be related to the complexity and highly risky nature of these cases but also to the low number of procedures performed in each centre and by each surgeon that does not allow the development of an expertise and the improvement of the ad hoc surgical skills.

Similarly to previous reports, we found that patients undergoing surgery temporarily closer to the index MI were more likely to die.^{7,10-12} Immediately after the MI, tissues are more friable, and this makes the operation more technically demanding. Ideally one would like to let the myocardium have the time to recover and reorganize in a firmer fibrotic tissue which makes stitching less complicated and more efficient. However, patients undergoing early surgery are usually presenting with a more clinically deteriorated and unstable conditions and therefore, it is not always possible to wait for the myocardium to recover. On the other hand, patients

who are more stable can tolerate waiting for surgery and, therefore, their outcomes are traditionally reported to be better.

There is no consensus on the optimal timing for VSD surgical repair. Current guidelines recommends early surgery in patients presenting with severely impaired hemodynamic conditions and delayed repair in stable patients or patients with therapy-controlled acute heart failure.¹³ Patients presenting with deteriorated hemodynamic status may benefit from implantation of mechanical support devices, such as IABP or extracorporeal life support, to delay the surgery and wait for the condition of the patient to be more stable and the myocardium less friable. In our cohort, all patients requiring a preoperative mechanical support received an IABP, sometimes combined with Impeller. However, in patients with cardiogenic shock the use of preoperative mechanical support achieved comparable operative mortality compared to patients managed medically. This is consistent with what was reported by Vondran et al.¹⁴ who recently investigated the role of mechanical support in 53 patients with VSD and cardiogenic shock and found that use of preoperative IABP was not of further benefit for patients waiting for surgery. Nevertheless, contrasting findings on this matter are present. The report from the STS database showed that the use of preoperative or intraoperative IABP was associated with worse operative outcomes.⁷ These conflicting results should be interpreted within the context of a highly

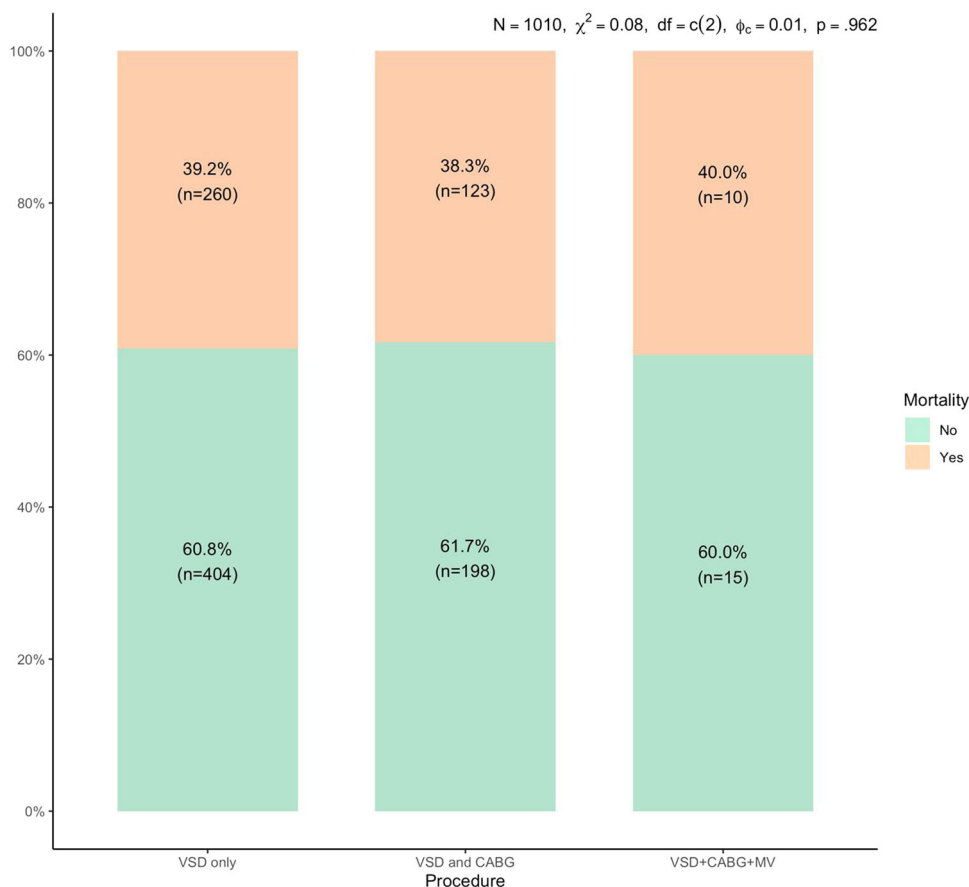


FIGURE 4 Operative mortality following surgical repair of ventricular septal defect (VSD) according to the type of procedure (isolated VSD repair; VSD and coronary artery bypass grafting [CABG]; VSD repair and CABG and mitral valve [MV] surgery). CABG, coronary artery bypass grafting; MV, mitral valve; VSD, ventricular septal defect

heterogenous clinical scenario in which different degrees of haemodynamic instability are included and different criteria for patient selection and indication are used. Therefore, it is difficult to dictate a general rule to be applied to all patients.

To our knowledge, this was the first study reporting on the outcomes of VSD repair with concomitant CABG and mitral valve procedure. VSD isolated repair or combined with CABG alone or with mitral valve procedures carried a similar early mortality rate. Previous reports have shown a benefit of coronary revascularization at the same time of VSD repair in terms of short and long-term mortality.^{15–17} On the other hands, other have reported no survival benefit.^{18,19} Although the longer ischemic time required to perform CABG could be detrimental for patient's outcome, it is reasonable to think that coronary revascularization in patients with coronary artery disease could only improve their long-term prognosis by reducing the ischemic burden and therefore, suggesting that CABG should be attempted together with VSD repair whenever possible.

This approach may provide a better stabilization of the hemodynamic conditions of the patients after surgery which could ensure a survival benefit.

Besides providing an overview of the trends and outcomes after VSD surgical repair in the United Kingdom, our findings should be used to benchmark the outcomes of the more commonly used

percutaneous closure devices. Since the first description of percutaneous transcatheter closure of post-MI VSD by Lock et al. in 1988,²⁰ several other case reports or small single-centre case series have been published.¹² The most common indications for this less-invasive procedure are patients clinically unstable and with prohibitive surgical risk, patients with residual shunt after VSD surgical repair or as a bridge strategy to surgery. Percutaneous closures are mainly limited by the VSD size, as VSD >35 mm is not amenable by transcatheter devices, and also by the difficulty in dealing with the necrotic margins of the VSD which could jeopardize the stability of the device. The reported success rate of this strategy is around 90% but mortality remains high and not inferior to surgically-managed patients.^{2,12} Finally, data on long-term outcomes, especially residual shunt and durability of the devices, are still lacking. Further evidence is required to identify a pivotal role of percutaneous strategies compared to surgery in the management of post MI VSD.

5 | LIMITATIONS

The findings of this study should be interpreted within the context of some limitations. Firstly, this is a retrospective study and residual confounders could have influenced our results. Second, the NACSA

dataset does not record variables which could have added strength and granularity to our analysis. For example, similarly to the STS database, there is no information on the anatomical location of the VSD (anterior vs. posterior) and on the surgical repair technique used. No data is provided regarding the echocardiography assessment of the defect, both pre- and postoperatively (size, preoperative shunt entity, postoperative residual shunt). Thirdly, we did not have long-term mortality available for this cohort and therefore no conclusion on the durability of the surgical repair can be drawn. Finally, a relevant selection bias is present in this analysis as no information were available for patients with VSD who died before surgery and, therefore, it is likely that sicker patients died before surgery and were not captured within this analysis.

TABLE 4 Results of the generalized linear mixed effect model for the identification of risk factors associated with in-hospital mortality

Predictors	Mortality		
	Odds ratios	CI	<i>p</i>
(Intercept)	0.02	0.00–0.16	<.001
Age	1.03	1.02–1.05	<.001
CCS class 3 or 4	1.27	0.90–1.79	.173
MI < h	Ref		
MI 6–24 h	0.58	0.20–1.69	.317
MI 1–30 days	0.35	0.12–0.99	.047
MI > 31 days	0.25	0.08–0.80	.019
No PCI	Ref		
<24 h, same admission	2.38	1.34–4.23	.003
>24 h, same admission	1.66	1.07–2.59	.024
>24 h, previous admission	0.94	0.41–2.18	.887
Diabetes	1.30	0.85–1.99	.234
Poor LVEF (<30%)	Ref		
Moderate LVEF (30%–50%)	0.67	0.48–0.94	.021
Normal LVEF (>50%)	1.28	0.84–1.96	.245
Cardiogenic shock	1.55	1.09–2.19	.014
Inotropic support	1.05	0.74–1.49	.779
Unstable angina	0.88	0.62–1.25	.478
Ventilation preoperatively	1.04	0.61–1.77	.877
Elective	Ref		
Urgency	2.61	0.58–11.70	.211
Emergency	7.32	1.63–32.87	.009
Salvage	11.82	2.43–57.57	.002
CKD	1.72	1.18–2.53	.005

(Continues)

TABLE 4 (Continued)

Predictors	Mortality		
	Odds ratios	CI	<i>p</i>
CABG	1.10	0.81–1.48	.544
MVP	1.40	0.50–3.92	.524
Random effects			
σ^2	3.29		
τ_{00} Consultant	0.03		
τ_{00} HospCode	0.09		
τ_{00} Year	0.00		
ICC	0.03		
N Consultant	379		
N HospCode	42		
N Year	23		
Marginal R^2 /Conditional R^2	0.280/0.305		

Note: Bold values indicate statistically significant *p* values.

Abbreviations: AF, atrial fibrillation; BMI, body mass index; CABG, coronary artery bypass grafting; CCS, Canadian Cardiovascular Society; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accidents; LVEF, left ventricular ejection fraction; MI, myocardial infarction; MVP, mitral valve procedure; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; PVD, peripheral vessel disease; TIA transient ischemic attack; UA, unstable angina; VF, ventricular fibrillation.

6 | CONCLUSIONS

Post MI VSD remains a dreaded mechanical complication characterized by high surgical operative mortality. A delayed operation, whenever possible, appears to be the most beneficial strategy to reduce mortality. Concomitant procedures (CABG and mitral valve surgery) should not be avoided as this study showed no higher mortality for those patients. Further evidence, especially comparative studies of surgical versus percutaneous strategy, is needed as to identify the most beneficial treatment pathway for these patients.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTIONS

Concept and design: Arnaldo Dimagli, Gustavo Guida, Shubhra Sinha; Data analysis and interpretation: Arnaldo Dimagli, Gustavo Guida;

Data collection: Arnaldo Dimagli, Shubhra Sinha; **Statistics:** Arnaldo Dimagli; **Drafting article:** all authors; **Critical revision of the article:** all authors; **Approval of the article:** all authors.

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