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The Role of VA-ECMO and Heart Transplantation in the Management of Ischemic Ventricular Septal Rupture

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Abstract

Ventricular septal rupture (VSR) is a rare and often fatal complication of myocardial infarction when managed conservatively. Management strategies for ischemic VSR have evolved in recent years. This retrospective study includes patients with ischemic VSR admitted between July 2014 and October 2023 at the Quebec Heart and Lung Institute. Primary outcomes were 30-day and three-year all-cause mortality. Among the 31 patients included (66 ± 11 years; 61% men), 19 had antero-apical and 12 had posterior VSR. Twenty patients developed cardiogenic shock before surgery, including nine who required veno-arterial extracorporeal membrane oxygenation (VA-ECMO). These patients more frequently had severe right ventricular dysfunction ($p < 0.001$) and posterior VSR ($p = 0.041$). Two patients died before surgery, 23 underwent VSR repair, and six underwent heart transplantation. Compared with patients undergoing VSR repair, transplant recipients more frequently had severe right ventricular dysfunction ($p < 0.001$) and posterior VSR ($p = 0.012$). Four of six transplant recipients were still alive at one year. Survivors had a longer median interval between myocardial infarction and surgery than non-survivors (10 vs. 4 days, $p = 0.009$). Thirty-day all-cause mortality was 35.5% and the three-year all-cause mortality was 45.2%. This study supports VA-ECMO and heart transplantation as potential options in highly selected patients with post-infarction VSR.

Keywords: ventricular septal rupture; acute myocardial infarction; veno-arterial extracorporeal membrane oxygenation; right ventricular dysfunction; heart transplantation

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1. Introduction

Ventricular septal rupture (VSR) is a rare mechanical complication of myocardial infarction. When managed conservatively, mortality rate is up to 100% [1,2]. With surgical VSR repair, the mortality rate has been reported to be as high as 50% in some case series, particularly those that did not utilize veno-arterial extracorporeal membrane oxygenation (VA-ECMO) support or heart transplantation [3–5]. Nevertheless, several risk factors influence the prognosis of patients presenting with post-infarction VSR, including older age, renal insufficiency, extent of coronary artery disease, hemodynamic instability and cardiogenic shock, early surgical VSR repair, severe right ventricular (RV) dysfunction, as well as location and morphology of VSR [3,6,7]. A retrospective review of the Society of Thoracic Surgeons database from 1999 to 2010, including 2876 patients who underwent post-infarction VSR repair, demonstrated that patients undergoing surgery within the first

seven days had a mortality rate of 54.1%, compared with 18% among those undergoing surgery after seven days [8]. In this study, the highest mortality rate was observed among patients who underwent surgery within the first six hours after myocardial infarction [8].

Therefore, in recent years, management strategies have evolved to include early initiation of VA-ECMO support in patients with profound cardiogenic shock as a bridging strategy to delayed surgical interventions. Indeed, allowing myocardial tissue healing before the surgery is associated with better prognosis [7]. Moreover, heart transplantation in selected cases where conventional surgery poses excessive risks may be considered [9–13]. The contribution of heart transplantation in ischemic VSR is mainly limited to case series or case reports. Across case reports and national registries, heart transplantation for ischemic VSR remains exceptionally rare but can be an effective option in carefully selected, high-risk patients [5,12,14]. Most reported cases show survival beyond hospitalization, with acceptable short- and mid-term outcomes, supporting transplantation as a potential bailout or definitive strategy when conventional surgical repair is not feasible [13]. In a selected population of patients with particularly posterior ventricular septal defect, severe RV dysfunction, and profound shock, the alternative of temporary support pending urgent heart transplantation probably appears reasonable [6]. Clearly, the optimal management of ischemic VSR remains highly complex and continues to pose major clinical challenges.

This study reviews the impacts of evolving management strategies for ischemic VSR over the past decade, including the use of VA-ECMO support and heart transplantation, at a tertiary referral centre, the Quebec Heart and Lung Institute–Laval University.

2. Material and Methods

This retrospective observational study included patients aged ≥18 years who were admitted with ischemic VSR between July 2014 and December 2023 at the Quebec Heart and Lung Institute–Laval University, with the last patient enrolled in October 2023. An echocardiography confirming VSR was required for inclusion. The only exclusion criterion was the absence of a documented VSR. Clinical data were collected from medical records, including surgical protocol, the use of VA-ECMO and intra-aortic balloon pump (IABP), and outcomes. The left ventricular ejection fraction (LVEF), VSR size and location, as well as the RV function (classified as normal, mild, moderate or severe dysfunction, according to current guidelines [15]) were collected from echocardiography reports. Cardiogenic shock was defined as an end-organ hypoperfusion requiring vasopressors or inotropic support to maintain cardiac output [16]. All patients were evaluated by a multidisciplinary heart team. VA-ECMO support was considered in cases of cardiogenic shock refractory to vasopressors and inotropic therapies, severe RV dysfunction or complex VSR associated with high surgical risk. The final decisions to use VA-ECMO support and to subsequently list the patients for heart transplantation were based on the heart team's assessment, on a case-by-case basis.

The choice of surgical repair technique and patch material was left to the surgeon's discretion. The techniques used included the David infarct exclusion technique and the traditional Daggett direct septal closure technique. Daggett et al. introduced infarctectomy and Dacron patch reconstruction of the interventricular septum and infarcted ventricular wall, with apical VSDs treated by apical amputation and wall approximation [17–20]. David et al. subsequently introduced infarct exclusion, which avoids infarctectomy by excluding the infarcted myocardium from the left ventricular cavity using an endocardially sutured pericardial patch [17,21,22].

Primary outcomes were 30-day and three-year all-cause mortality. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Quebec Heart and Lung Institute–Laval University (IUCPQ-UL) (#2027-4602;

approved on 19 August 2026). Patient consent was waived by the Ethics Committee of the Quebec Heart and Lung Institute–Laval University due to the retrospective nature of the study.

Statistical Analysis

Continuous variables were tested for distribution normality using the Shapiro–Wilk test and expressed as mean ± standard deviation (SD) or median and interquartile range (IQR), as appropriate. Categorical variables were presented as numbers and proportions (%). Comparative analyses were performed using the Student *t*-test or the Mann–Whitney *U* test for continuous variables, and the Chi-square test or the Fisher's exact test for categorical variables. Statistical analyses were performed using Stata 11.2 (StataCorp LP, College Station, Texas, USA), and $p < 0.05$ defined a statistically significant difference.

3. Results

This retrospective study included 31 patients with ischemic VSR treated at a tertiary cardiac care center between 2014 and 2023 (mean age, 66.0 ± 10.8 years; 61% males). Baseline clinical characteristics are summarized in Table 1. The mean LVEF was 41 ± 8%, and seven patients (23%) had a severe RV dysfunction. VSR was located in the antero-apical region in 19 patients (61%) and the posterior region in 12 (39%). Cardiogenic shock developed before surgery in 20 patients (64.5%), including nine who required VA-ECMO support.

Table 1. Clinical characteristics.

Variables.	Total ($n = 31$)	VA-ECMO Support ($n = 9$)	No VA-ECMO Support ($n = 22$)	*p* Value
Age (years)	66.0 ± 10.8	63.1 ± 4.3	67.2 ± 12.4	0.35
Sex (male)	19 (61%)	5	14	0.68
Body mass index (kg/m^2)	27.5 ± 4.4	27.3 ± 3.4	27.6 ± 4.8	0.86
History of CAD	1 (3.2%)	0	1	0.52
Hypertension	16 (51.6%)	5	11	0.78
Diabetes	12 (38.7%)	1	11	0.10
Dyslipidemia	15 (48.4%)	3	12	0.28
Former or active smokers	16 (51.5%)	2	14	0.05
Chronic kidney disease	3 (9.7%)	1	2	0.86
Creatinine (mmol/L)	117 ± 77	181 ± 110	91 ± 36	0.002
ALT (U/L)	295 ± 560	587 ± 838	175 ± 359	0.06
Lactate (mmol/L)	4.0 ± 3.5	6.9 ± 5.0	2.7 ± 1.5	0.002
Inferior STEMI	13 (41.9%)	7 (77.8%)	6 (27.3%)	0.010
Cardiogenic shock	20 (64.5%)	9 (100%)	11 (50%)	0.008
Thrombolysis	4 (12.9%)	1	3	0.85
PCI	17 (54.8%)	6	11	0.40
LVEF (%)	41 ± 8	40 ± 5	41 ± 9	0.62
Right Ventricular Dysfunction				
No dysfunction	7 (23.3%)	1 (11%)	6 (28.6%)	0.004
Mild dysfunction	4 (13.3%)	0	4 (19.1%)	
Moderate dysfunction	12 (40.0%)	2 (22.2%)	10 (47.6%)	
Severe dysfunction	7 (23.3%)	6 (66.7%)	1 (4.8%)	
VSR size (mm)	15 ± 8	17 ± 7	14 ± 9	0.38
Antero-apical VSR	19 (61.3%)	3 (33.3%)	16 (72.7%)	0.041
Posterior VSR	12 (38.7%)	6 (66.7%)	6 (27.3%)	

Data presented as mean ± standard deviation, median (interquartile range 25th–75th), or *n* (%). ALT: alanine aminotransferase; CAD: coronary artery disease; LVEF: left ventricular ejection fraction; PCI: percutaneous coronary intervention; STEMI: ST-elevation myocardial infarction; VA-ECMO: veno-arterial extracorporeal membrane oxygenation; VSR: ventricular septal rupture.

3.1. Mechanical Support Before Surgery

Among the 31 patients included in the study, 26 received temporary mechanical circulatory support: IABP alone ($n = 17$); VA-ECMO alone ($n = 1$), or combined VA-ECMO and IABP support ($n = 8$). Among the 25 patients who received IABP support, 22 had the device inserted on the day of VSR diagnosis, while three did not have IABP support maintained until surgery.

Among the nine patients who received VA-ECMO support, eight ultimately had surgery: two underwent VSR repair, and six had heart transplantation. Patients requiring VA-ECMO support were more hemodynamically unstable, as evidenced by cardiogenic shock in all, elevated lactate ($p = 0.002$) and creatinine ($p = 0.002$) levels, as well as a higher prevalence of severe RV dysfunction ($p < 0.001$) and posterior VSR ($p = 0.041$). Patients under VA-ECMO support had higher rates of bleeding (67% vs. 27%; $p = 0.041$) and dialysis (55% vs. 9%; $p = 0.005$) during hospitalization, but no difference was observed regarding transient ischemic attack/stroke ($p = 0.24$) or limb ischemia ($p = 0.21$). The median duration of VA-ECMO support prior to surgery was six days (IQR: 4–8).

Five patients required continued VA-ECMO support postoperatively, for a maximum of three days. Three of these five patients died during hospitalization. Decision regarding VA-ECMO weaning were made on a case-by-case basis by the heart team. When feasible, VA-ECMO was discontinued at the end of surgery if successful weaning from extracorporeal circulation was achieved. Further details on patients who received VA-ECMO support are provided in Table S1.

3.2. Surgical Intervention

Surgical data are reported for 29 patients, as two patients died before surgery. One died from cardiorespiratory arrest before VA-ECMO could be initiated. The other developed aortic valve thrombosis while on VA-ECMO; subsequent investigation revealed a renal malignancy, and the patient was transitioned to palliative care. Of the 29 patients who underwent surgical intervention, 23 had surgical VSR repair—including one following a percutaneous repair attempt — and six patients had heart transplantation.

3.2.1. Ventricular Septal Rupture Repair

Of the 23 patients who had VSR repair, 13 procedures were performed using the David infarct exclusion technique, nine using the traditional Daggett direct septal closure technique, and one involved surgical closure around a septal occluder previously placed during a percutaneous repair attempt. The surgical approach was predominantly a trans-infarct approach to the left ventricle ($n = 15$, including one patient with a previous percutaneous repair attempt), while other approaches were used less frequently: the right ventricle ($n = 2$); the right atrium ($n = 1$); the right atrium and the right ventricle ($n = 3$); a trans-infarct approach to the left ventricle and the right ventricle ($n = 1$); and a trans-septal approach ($n = 1$). The patch material was a bovine pericardial patch ($n = 12$), a dacron patch ($n = 8$), or a Teflon patch ($n = 1$). The patient who underwent VSR closure using an Amplatzer device did not require an additional patch, while one other patient underwent surgical repair without patch placement. The choice of surgical repair technique and patch material was left to the surgeon's discretion. Ten patients had associated left ventricular aneurysm or papillary muscle involvement in addition to the VSR. The strategies for LV aneurysm and papillary muscle involvement were variable, including infarctectomy for aneurysms ($n = 1$), aneurysm resection ($n = 2$), Dor procedure ($n = 2$), exclusion of the aneurysm with a second patch ($n = 2$), Teflon bands to reduce aneurysms ($n = 2$), and one had an aneurysmal pericardial rupture reconstructed using a bovine pericardial patch. Other concomitant procedures included coronary artery bypass graft ($n = 12$) and valve replacement ($n = 2$). Despite attempted closure, residual

ventricular septal defect was observed in 11 patients (47.8%), four of whom required another surgery. Ten of these 11 patients were alive at one-year follow-up.

3.2.2. Heart Transplantation

In this study, six patients underwent heart transplantation. Patients were referred to a heart transplantation based on irreparable posterior defect ($n = 2$), severe RV failure ($n = 2$) or both ($n = 2$), and the non-repairability was a pre-operative decision in all patients. Compared to patients who underwent surgical VSR repair, patients who had a heart transplantation more frequently presented severe RV dysfunction ($p < 0.001$) and posterior VSR ($p = 0.012$), but there were no significant differences in LVEF ($p = 0.97$) and VSR size ($p = 0.12$). Among the six transplanted patients, four were still alive at one-year follow-up, while three still alive at three-year follow-up.

3.3. Outcomes

Overall, the 30-day all-cause mortality was 35.5% ($n = 11$), cardiovascular causes being the most common. The 30-day survivors were younger than non-survivors (62.9 ± 9.6 vs. 71.7 ± 10.7 years old; $p = 0.025$). At 30 days, there was no difference between survivors and non-survivors regarding the LVEF ($p = 0.51$), VSR size ($p = 0.16$), presence of severe RV dysfunction ($p = 0.76$), or VSR location ($p = 0.57$). However, survivors had a longer interval between myocardial infarction and surgical intervention compared to non-survivors (10 (5.5–13.5) vs. 4 days (3–4); $p = 0.009$). The Kaplan–Meier survival estimates showed greater survival in patients who underwent surgery at least six days after myocardial infarction ($p = 0.015$; hazard ratio 0.14; Figure 1). The three-year all-cause mortality was 45.2% ($n = 14$). The management and outcomes of the cohort are presented in Table 2.

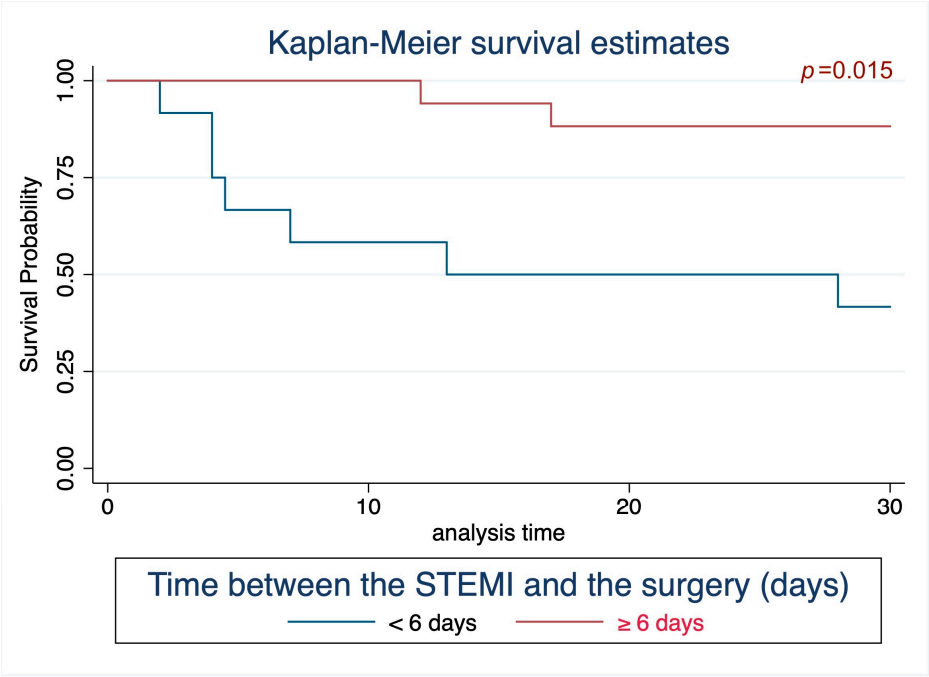


Figure 1. Kaplan–Meier survival curves at 30-day follow-up. Median time between myocardial infarction and surgery in our cohort was six days. The 29 patients who underwent surgery were separated into two groups based on the median time between myocardial infarction and surgery (<6 days and ≥6 days). The Kaplan–Meier survival estimates demonstrated that survival time is longer in patients waiting at least six days before surgery ($p = 0.015$; hazard ratio 0.14). STEMI: ST-segment elevation myocardial infarction.

Table 2. Management and outcomes.

Variables	Total (n = 31)	VA-ECMO Support (n = 9)	No VA-ECMO Support (n = 22)	p Value
Intra-aortic balloon pump	25 (80.7%)	8	17	0.46
Time interval AMI-surgery (days)	6 (4–12)	8 (5.5–10.5)	6 (4–13)	0.68
Surgery *	29	8	21	0.50
Transplantation	6	6	0	<0.001
VSR repair surgery	23	2	21	<0.001
Concomitant CABG	12	0	12	0.005
Perioperative mortality	3	1	2	0.81
Hospital mortality	11	4	7	0.51
30-day mortality	11	4	7	0.51
3-year mortality	14	5	9	0.46
Causes of 3-Year Mortality (n = 14)				
Cardiogenic shock	8	3	5	0.54
Multiple organ failure	1	1	0	0.11
Respiratory failure	4	1	3	0.85
Neurological cause	1	0	1	0.52

Data presented as mean ± standard deviation, median (interquartile range 25th–75th), or n (%). AMI: acute myocardial infarction; GABG: coronary artery bypass graft surgery; VA-ECMO: veno-arterial extracorporeal membrane oxygenation; VSR: ventricular septal rupture. * Surgery includes transplantation, VSR repairs, and percutaneous repairs. The surgery-related data included the 29 patients who had surgery.

4. Discussion

The present study examines the management and outcomes of post-infarction VSR during the past decade in Quebec City. Considering the rarity of ischemic VSR, it is one of the largest cohorts of heart transplant recipients for post-infarction VSR. This study supports heart transplantation as a viable option in highly selected cases of post-infarction VSR, and is consistent with the literature on the importance of a well-timed surgery and judicious use of VA-ECMO support as a bridging strategy. Our findings suggest that hemodynamically stable patients may benefit from a delayed surgical VSR repair, while unstable patients can be managed with VA-ECMO support as a bridge to surgical VSR repair or heart transplantation.

4.1. Timing of Surgery

Ischemic VSR typically develops between two days to two weeks following myocardial infarction. The tissue healing generally requires approximately two weeks [7]. Historically, clinical management often favoured immediate surgical repair, sometimes performed on the very day the diagnosis was confirmed. However, observational data suggest that delayed repair yields better outcomes, likely due to the increased time for tissue healing, which leads to reduced friability of the septal tissue during surgery. The highest mortality rate is observed when surgical VSR repair is performed within the first 24 h of initial presentation, while mortality decreases to 40% when surgery is delayed beyond seven days [7]. Therefore, current literature supports early preoperative mechanical circulatory support in high-risk patients with post-myocardial infarction VSR as a bridging strategy, allowing time for infarcted tissue to heal before definitive surgery [9–12,23,24]. Furthermore, resolution of the initial cardiogenic shock and completion of the initial acute myocardial infarction are important considerations. Surgery performed during ongoing infarction carries a higher risk of suture dehiscence due to friable necrotic tissue that may not subsequently adequately hold sutures. Residual shunt is not uncommon following surgical repair of ischemic VSR. Previous studies have reported residual shunt rates ranging from 21% to 40% following

surgical repair of post-infarction VSR, with substantial variability across surgical techniques and patient populations [25–27]. In a study of 32 patients with ischemic VSR, Hussein et al. reported a residual ventricular septal defect rate of approximately 25% [27]. Isoda et al. reported a residual ventricular septal defect in 29% of seven patients who underwent surgical repair [25]. Deja et al. evaluated 117 patients who underwent surgical repair of ischemic VSR and reported a residual shunt rate of 40% [26]. Notably, in the latter study, the presence of a residual shunt was not associated with increased mortality. In the present study, residual ventricular septal defect occurred in 47.8% of patients; however, only four of the 11 patients with residual shunt required repeat surgery, representing 17.4% of the patients who underwent surgical VSR repair. Therefore, our findings are consistent with previously reported reintervention rate of approximately 20% in some cohorts [28]. In the present study, 10 of these 11 patients with residual shunt were alive at one-year follow-up. Therefore, despite the relatively high incidence of residual ventricular septal defect, its presence did not necessarily translate into an unfavorable outcome.

4.2. Role of Mechanical Support

The VA-ECMO support and transcatheter axial flow devices, such as Impella, both play roles in the management of ischemic VSR, each offering different advantages and limitations [29–31]. Traditionally, the use of Impella in patients with VSR was discouraged due to concerns regarding the risk of embolization from aspiration of necrotic myocardial debris [31,32]. Although Impella provides effective left ventricular unloading, it may lead to shunt reversal from right to left. VA-ECMO improves end-organ perfusion but is associated with a risk of device-related complications, such as aortic root thrombosis, limb ischemia, bleeding, and infection [31]. Moreover, VA-ECMO may necessitate additional ventricular unloading measures, such as IABP [29,31,33]. In the present study, among the 29 patients who underwent surgical intervention, 31% received VA-ECMO support, while 88.9% of patients with VA-ECMO support also received concomitant IABP, and few device-related complications were observed. This observation is consistent with recent studies showing that the combination of VA-ECMO and IABP is the most commonly used mechanical circulatory support strategy in this patient population [34]. However, only VA-ECMO and IABP were used, as our centre does not currently use the Impella device. VA-ECMO support was considered by the heart team for patients with profound cardiogenic shock and hemodynamically significant VSR, and in whom progression to refractory shock was anticipated, especially in patients with severe RV dysfunction precluding urgent repair surgery. Despite being more critically ill, patients requiring VA-ECMO support did not experience higher mortality compared to those who were managed without VA-ECMO support. Furthermore, in this retrospective study, survival appeared to be better among patients in whose surgical repair was delayed by at least six days following myocardial infarction. In this context, VA-ECMO support played a pivotal role by stabilizing hemodynamically critical patients and enabling postponement of surgery by a median interval of eight days. The INTERMACS registry has demonstrated that durable ventricular assist devices may have a role even in the setting of acute myocardial infarction [35]. However, their specific role in patients with post-infarction VSR remains poorly defined. Only a few cases describing the use of left ventricular assist devices (LVAD) in patients with post-infarction VSR have been reported in the literature [34]. In a recent US multicenter analysis of 117 patients with ischemic VSR, three patients underwent concomitant durable LVAD implantation and VSD repair, while another three underwent LVAD implantation following VSD repair [34]. Two deaths occurred among these six patients. Preserved RV function is essential for LVAD implantation, which remains challenging in this setting given the presence of a left-to-right shunt. Although LVAD support may be considered in selected patients, its role in this population

remains uncertain, and no patients with VSR have undergone LVAD implantation in the present study.

4.3. Role of Heart Transplantation

Heart transplantation for ischemic VSR remains a rare intervention. In a retrospective study including 97 patients with ischemic VSR at Toulouse University Hospital between 2009 and 2020, one-year mortality was 86%, but only one patient received heart transplantation [30]. In a systematic review including 14 case reports between 1994 and 2015 of patients with ischemic VSR treated with heart transplantation as a primary or bailout strategy, a total of 12 patients benefited from heart transplantation, but only six patients had a six-month follow-up [14]. In the CIVIAM registry (2008–2018), a retrospective multicenter study carried out in Spain that included 120 patients with ischemic VSR, a total of six patients had heart transplantation, and one of them died during hospitalization [12]. In the UK National Registry (2010–2021) that included 362 patients with ischemic VSR, the only patient to undergo heart transplantation was still alive at five-year follow-up [5]. In the National Inpatient Database from the United States, among 4765 ischemic VSR, 30 patients underwent a heart transplantation (0.6%) between 2016 and 2021, supporting heart transplantation as an option in special circumstances [13]. Over the past decade, heart transplantation has emerged as a feasible therapeutic option in cases where conventional surgical VSR repair carries prohibitive risk and an unfavourable prognosis [36]. In the present study, among the 29 patients who underwent surgical intervention, 21% had a heart transplantation. It should be noted that all six patients who underwent heart transplantation required VA-ECMO support before transplantation, representing six of the nine patients treated with VA-ECMO. These patients had clinical characteristics that made surgical repair a less favorable treatment option. We observed that an irreparable posterior defect was the main reason for heart transplantation listing in four of the six transplanted patients. Among the 12 patients with posterior VSR in the present study, five underwent heart transplantation, while three died. The use of VA-ECMO in selected patients and consideration of heart transplantation in highly selected cases may partly explain the lower mortality observed in the present study compared with previously published reports. However, given the retrospective nature of our study, this association should be interpreted with caution. Nevertheless, heart transplantation should be considered a last-resort, life-saving strategy rather than a first-line treatment.

4.4. Historical Cohort Comparison

Cinq-Mars et al. previously reported outcomes in 34 patients who underwent VSR repair at the Quebec Heart and Lung Institute–Laval University between 1991 and 2014 [3]. In this historical cohort, the mean age was 69 ± 7 years and the mean LVEF was 44 ± 14%. Similar to the present cohort, a substantial proportion of patients presented with cardiogenic shock (71% vs. 64.5% in the present cohort). However, preoperative IABP support was used in only 65% of patients, and only one patient received VA-ECMO support and one underwent heart transplantation. The 30-day mortality in this cohort was 65%, compared with 35.5% in the present study, in which nine patients received VA-ECMO support and six underwent heart transplantation. Importantly, consistent with our findings, Cinq-Mars et al. identified a shorter interval between myocardial infarction and surgery as an independent predictor of 30-day mortality [3].

Considering the present study and the previous published cohort that included the patients between 1991–2014 at our institute [3], seven patients with ischemic VSR underwent heart transplantation at the Quebec Heart and Lung Institute–Laval University since 1991. Among them, four were still alive at the three-year follow-up, corresponding to a 57%

survival rate. The reasonable three-year survival rate among transplanted patients is encouraging, particularly for posterior VSR, which continues to present a high mortality rate even with delayed VSR repair. In light of the improvement in survival observed over the last decade, we propose a decision-making algorithm for managing post-infarction VSR (Figure 2).

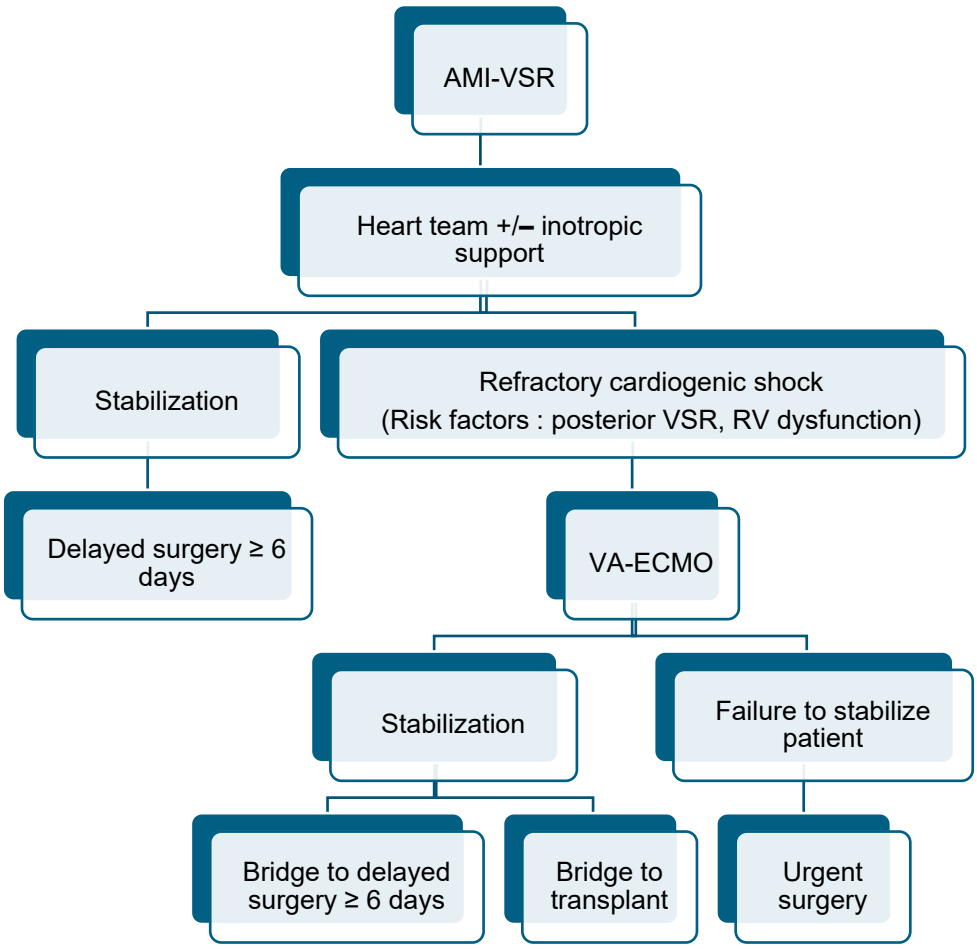


Figure 2. A decision-making algorithm for the management of ischemic ventricular septal rupture. The reduction in mortality is associated with better timing of surgical intervention, judicious use of VA-ECMO support, and referral for heart transplantation in cases where surgical repair carries high risks. We observed longer survival time in patients waiting at least six days between myocardial infarction and surgery. Therefore, hemodynamically stable patients may benefit from delayed surgical repair, while unstable patients can be managed with VA-ECMO support as a bridge to definitive surgery or heart transplantation. The stabilization period allows myocardial tissue healing to optimize surgery success and provides an opportunity to plan the most appropriate surgical approach, including heart transplantation if the ischemic VSR is too severe to make surgical repair a viable option. The patients who needed heart transplantation presented more often with severe RV dysfunction and posterior VSR. AMI: acute myocardial infarction; VA-ECMO: veno-arterial extracorporeal membrane oxygenation; RV: right ventricle; STEMI: ST-segment elevation myocardial infarction; VSR: ventricular septal rupture.

4.5. Limitations

This study is retrospective and is limited by the inherent characteristics of this design, the small sample size, and the clinical heterogeneity of the cohort. These factors limit the statistical power and the generalizability of our findings. The significant hemodynamic instability of patients requiring VA-ECMO support represents an inherent bias, as their prognosis is invariably poor. Finally, although a heart team evaluated all patients, the decisions

to initiate VA-ECMO support and to subsequently list patients for heart transplantation were on a case-by-case basis. Despite these limitations, this study is unique and provides valuable insights into the complex management of post-myocardial infarct VSR.

5. Conclusions

This retrospective study comprehensively examines the management of ischemic VSR in a tertiary cardiology centre. It supports heart transplantation as a viable therapeutic option for carefully selected patients with very poor prognosis following post-infarction ventricular septal rupture. In hemodynamically stable patients, delayed surgical repair seems to be associated with favourable outcomes. In contrast, among unstable patients, VA-ECMO support may serve as an effective bridge to delayed surgery or heart transplantation in selected cases, although further studies are needed.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/jcdd13110563/s1, Table S1: Characteristics of patients who have benefited from VA-ECMO support *.

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Informed Consent Statement: The requirement for informed consent was waived by the Ethics Committee of the Quebec Heart and Lung Institute – Laval University as the study involved the retrospective analysis of non-identifiable data.

Data Availability Statement: The datasets presented in this article are not readily available. Requests to access the datasets should be directed to Mario Senechal.

Conflicts of Interest: The authors declare no conflict of interest.

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