European Heart Journal - Case Reports
doi:10.1093/ehjcr/ytab141

Emergency sandwich patch repair *via* right ventricular incision for postinfarction ventricular septal defects: a case series

Yusuke Shimahara [1]*, Satsuki Fukushima [1], Shin Yajima[1], Naoki Tadokoro [1], Takashi Kakuta[1], Yasuhide Asaumi [2], Junjiro Kobayashi[1], and Tomoyuki Fujita [1]

[1]Department of Cardiovascular Surgery, National Cerebral and Cardiovascular Center, 6-1 Kishibe-Shimmachi, Suita, Osaka 564-8565, Japan; and [2]Department of Cardiovascular Medicine, National Cerebral and Cardiovascular Center, 6-1 Kishibe-Shimmachi, Suita, Osaka 564-8565, Japan

Received 12 November 2020; first decision 30 November 2020; accepted 29 March 2021

Background The surgical treatment for postinfarction ventricular septal defect (VSD) remains challenging, especially in emergency cases. Several authors have reported the efficacy of a sandwich patch VSD repair *via* a right ventricular (RV) incision. However, this procedure remains uncommon, and its efficacy is still unknown, especially when performed under an emergency.

Case summary We were able to perform sandwich patch VSD repair *via* an RV incision on seven consecutive patients with VSD following an ST-segment elevation myocardial infarction (STEMI) from March 2017 to December 2019. Bovine pericardial patches were used for sandwich patches. Two patients developed inferior STEMI, and the other patients developed anterior STEMI. Six patients received intra-aortic balloon pump prior to surgery, and the other received extracorporeal membrane oxygenation with Impella. The interval between the diagnosis of VSD and surgery was within 1 day in all patients except one (5 days). All seven patients underwent VSD repair in the emergency status. Four patients underwent concomitant coronary artery bypass grafting. The hospital mortality rate was 14.3% (1/7). Early postoperative transthoracic echocardiography revealed that only one patient developed more than trace residual shunt. The postoperative right atrial pressure was not significantly elevated at ≤12 mmHg in all patients. No patient developed early postoperative prolonged low cardiac output syndrome.

Discussion In patients with postinfarction VSD, a sandwich patch VSD repair *via* an RV incision is a promising procedure with a low incidence of residual shunt development and hospital mortality, even in emergency cases.

Keywords Case report • Myocardial infarction • Postinfarction ventricular septal defect • Right ventricular incision • Sandwich patch repair

* Corresponding author. Tel: +81 6 6170 1070, Fax: +81 6 6170 1782, Email: shimahamomaon@gmail.com
Handling Editor: Michel PompeuSá
Peer-reviewers: Roberto Lorusso and AngelLuisFernandez Gonzalez
Compliance Editor: Max Sayers
Supplementary Material Editor: Ross Thomson

Learning points

- Sandwich patch ventricular septal defect (VSD) repair *via* a right ventricular (RV) incision results in less damage to the left ventricle than VSD repair *via* a left ventricular incision, and ventricular suture-line bleeding following the RV incision is not a common finding even in the acute phase of acute myocardial infarction.
- Transmural mattress sutures with large polytetrafluoroethylene pledgets allow surgeons to prevent myocardial cutting by the sutures and helps in the tight fixation of the sandwich patches on the myocardium.
- In patients with postinfarction VSD, a sandwich patch VSD repair *via* an RV incision is a promising procedure with a low incidence of residual shunt development and hospital mortality, even in emergency cases.

Introduction

The treatment for ventricular septal defect (VSD) following an acute myocardial infarction (AMI) remains challenging. Endocardial patch repair *via* a left ventricular (LV) incision, described as 'infarct exclusion', is a common surgical treatment for postinfarction VSD.[1] However, hospital mortality after surgical VSD repair was reported to be as high as 20–60%, especially in emergency cases.[2–5] Recently, several authors have reported the efficacy of a sandwich patch VSD repair *via* a right ventricular (RV) incision.[6–8] We also performed this procedure under a previous emergency case. However, this procedure remains uncommon, and its efficacy is still unknown, especially when performed under an emergency.

We were able to perform sandwich patch VSD repair *via* an RV incision on seven consecutive patients with VSD following an ST-segment elevation myocardial infarction (STEMI) from March 2017 to December 2019.

Surgical technique

For patients with an anterior wall AMI, a longitudinal right ventriculotomy was made along the left anterior descending artery (LAD) (*Figure 1*). During the right ventriculotomy, great care was required to avoid injury to the anterior papillary muscle in the right ventricle. The VSD was enlarged, at approximately 3 cm in diameter, which facilitated the insertion of the patch into the left ventricle and the placement of transmural stitches from inside of the left ventricle. Bovine pericardial patches (Edwards Lifesciences, Irvine, CA, USA) were used for sandwich patches. The first patch was cut into a circular shape with a diameter of 6–8 cm, as appropriate to the infarction area. The needles of the double-armed polypropylene sutures with a large polytetrafluoroethylene (PTFE) pledget (approximately 10 mm $\times$ 20 mm) were passed through the patch and then through the septum and LV free wall transmurally from the inside of the left ventricle at least 1.5 cm away from the edge of the VSD. We frequently used 3-0 Prolene sutures with MH needles (Ethicon, Inc., Somerville, NJ, USA). The patch was subsequently inserted into the LV cavity through the VSD. Then, a second patch was tailored to the appropriate size according to the area where the previous mattress sutures protruded out of the LV free wall and septum of the RV side. The existing needles of the double-armed sutures passed through the edge of the second patch with large PTFE pledgets. Before tying all the mattress sutures, a surgical glue [a BioGlue (CryoLife Inc., Kennesaw, GA, USA) or a Hydrofit (Terumo Corporation, Tokyo, Japan)] was applied to the cavity between the two patches. Eight pledgeted mattress sutures were frequently used to fix the sandwich patches. Finally, the right ventriculotomy was directly suture-closed (*Figure 1A*) or patch-closed (*Figure 1B*) using polypropylene sutures with either pericardial or PTFE strips.

For patents with an inferior wall AMI, a longitudinal right ventriculotomy was made along the posterior descending artery (PDA) (*Figure 2A*). Next, the sandwich patch repair was performed in a similar way to that in the anterior wall AMI cases. When the ruptured septum was large in size and extended close to the medial mitral annulus, the double-armed polypropylene sutures for the first patch were passed transmurally through the septum or the LV free wall at the base of the heart (*Figures 2B, and 3*). In these situations, a large patch, with a long-axis length of 10 cm or more, was needed. The second patch was tailored to the appropriate size according to the area where the previous mattress sutures protruded out of the septum of the RV side and the edge of the PDA-sided right ventricle (*Figure 2C*). After application of the surgical glue to the cavity between the two patches, all the mattress sutures were tied. The RV incision, including the second patch on the PDA-sided right ventricle, was suture-closed using polypropylene sutures with either pericardial or PTFE strips (*Figure 2D*).

Timeline

Patient	Age	Sex	Projected interval acute myocardial infarction to surgery (days)	Interval ventricular septal defect (VSD) diagnosis to surgery (days)	Primary percutaneous coronary intervention	VSD location	Preoperative mechanical support	Concomitant surgery	Postoperative course, complications	Postoperative transthoracic echocardiography residual shunt, left ventricular ejection fraction
1	82	Female	2	0	None	Inferior	Intra-aortic balloon pump (IABP)	Coronary artery bypass grafting (CABG) ×1	Postoperative day (POD) 5. Extubation POD 6. IABP off POD 132. Changing hospital (rehabilitation) POD 195. Discharge from hospital At 3 years. No cardiac event	None, 50%
2	60	Male	6	0	None	Apical	IABP Ventilation	Left ventricular (LV) rupture repair	POD 6. IABP off, extubation POD 74. Discharge from hospital At 3 years. No cardiac event	Trace, 33%
3	69	Female	11	6	Left anterior descending artery (LAD)	Apical	IABP	CABG ×1	POD 1. Extubation POD 6. IABP off POD 14. Changing hospital (rehabilitation) POD 33. Discharge from hospital At 1 year. No cardiac event	4.0 mm, 25%
4	71	Female	1	1	LAD	Apical	IABP	CABG ×3	POD 1. continuous hemodiafiltration POD5. IABP off POD 7. Extubation, computed tomography detected stroke with severe disability POD 33. Changing hospital (rehabilitation) POD 49. Worsened heart failure POD 51. Retuning to our hospital, pulmonary oedema, intubation POD 52. Hospital death	Trace, 46%
5	85	Male	1	1	LAD	Apical	Ventilation Extracorporeal membrane oxygenation (ECMO) Impella	LV rupture repair, IABP insertion, Impella off	POD 3. ECMO off POD 5. IABP off, extubation POD 30. Changing hospital (rehabilitation) POD 117. Discharge from hospital At 1 year. No cardiac event	None, 50%
6	87	Male	3	1	None	Anterior	IABP	CABG ×2	POD 4. Extubation POD 5. IABP off POD 23. Changing hospital (rehabilitation) POD 85. Discharge from hospital At 1 year. No cardiac event	None, 29%
7	69	Male	6	0	Right coronary artery	Inferior	IABP	None	POD 3. IABP off, extubation POD 17. Discharge from hospital At 6 months. No cardiac event	None, 43%

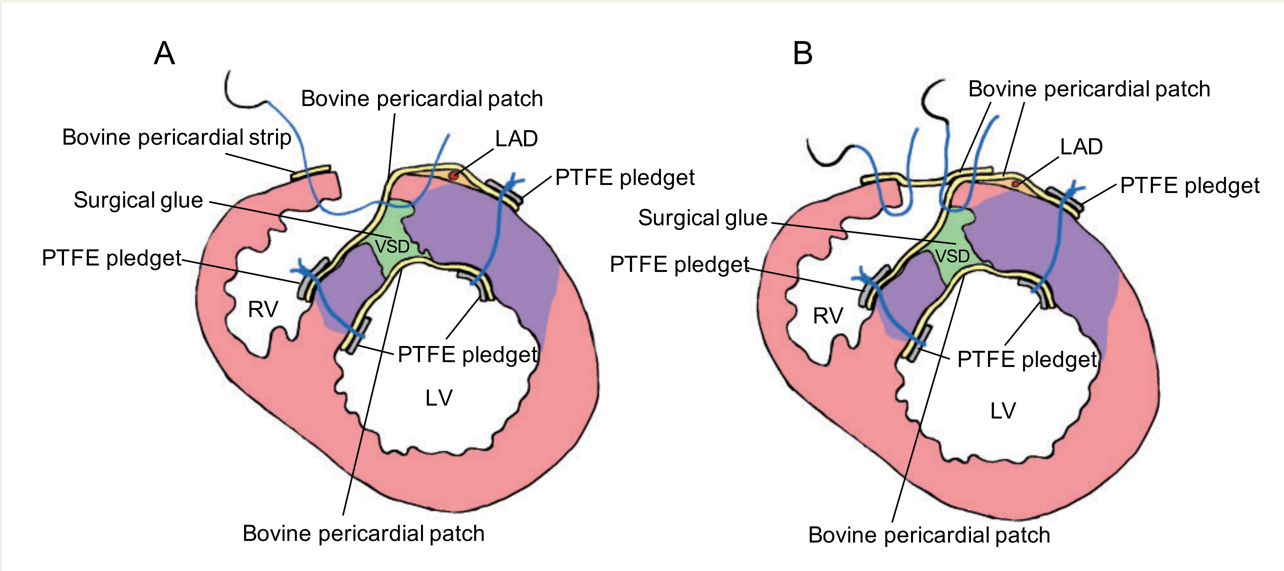

Figure 1 Sandwich patch ventricular septal defect repair *via* a right ventricular incision for anterior ventricular septal defect. A longitudinal right ventriculotomy was made along the left anterior descending artery. Sandwich bovine pericardial patches were placed using transmural polypropylene mattress sutures with polytetrafluoroethylene pledgets. A surgical glue was applied to the cavity between the two patches. The right ventriculotomy was directly suture-closed (*A*) or patch-closed with pericardial or polytetrafluoroethylene strips (*B*). LV, left ventricle.

Case presentation

The perioperative data of all seven cases are summarized in *Tables 1–4*.

Patient 1

An 82-year-old female patient was rushed to our hospital due to an inferior STEMI with concomitant shock. An intra-aortic balloon pump (IABP) was initiated, and transthoracic echocardiography (TTE) detected a VSD. Emergency VSD repair with coronary artery bypass grafting (CABG) to the LAD was performed. The postoperative course was uneventful with no residual shunt detected at follow-up after 3 years.

Patient 2

A 60-year-old male patient was referred to our hospital due to an anterior STEMI with concomitant shock. During emergency coronary angiography, the patient was intubated and underwent IABP initiation. Then, TTE detected both pericardial effusion and VSD. During the emergency VSD repair, the sandwich bovine pericardial patches were able to cover a myocardial tear in the surface of the infarct anterior wall that caused the coexistent LV oozing rupture. The postoperative course was uneventful with development of only a trace residual shunt at follow-up after 3 years.

Patient 3

A 69-year-old female patient with an anterior STEMI underwent emergency percutaneous coronary intervention (PCI) to the LAD and initiation of IABP at another hospital. A VSD was detected by TTE 4 days after PCI and was medically treated. However, the patient's haemodynamics deteriorated 9 days after PCI, and pulmonary artery catheterization revealed a step-up in oxygen saturation between the right atrium and the pulmonary artery. Then, the patient was emergently transferred to our hospital and underwent emergency VSD repair and CABG to the posterolateral artery. While TTE showed a residual shunt in the apex approximately 4 mm in size, no cardiac events occurred 1 year postoperatively.

Patient 4

A 71-year-old female patient with social withdrawal was rushed to our hospital due to an anterior STEMI and triple vessel coronary disease. Emergency PCI for the LAD failed, and IABP was initiated. The patient's haemodynamics deteriorated shortly after, and a VSD was detected by TTE. The patient underwent emergency VSD repair with CABG to the diagonal artery, posterolateral artery, and PDA. Although the patient developed perioperative stroke with a severe disability, the early postoperative haemodynamics was observed to be stable with an LV ejection fraction 46% and only a trace residual shunt. However, after changing hospitals for rehabilitation, the patient developed severe heart failure and was required to returned to our hospital. TTE revealed a worsened LV ejection fraction (25%) with a trace residual shunt. Further examination and treatment were refused by the patient's family, eventually leading to hospital death 52 days after surgery.

Patient 5

An 85-year-old male patient was emergency transferred to our hospital due to an anterior STEMI with a VSD. After emergency Impella 2.5 (Abiomed, Danvers, MA, USA) initiation and PCI for

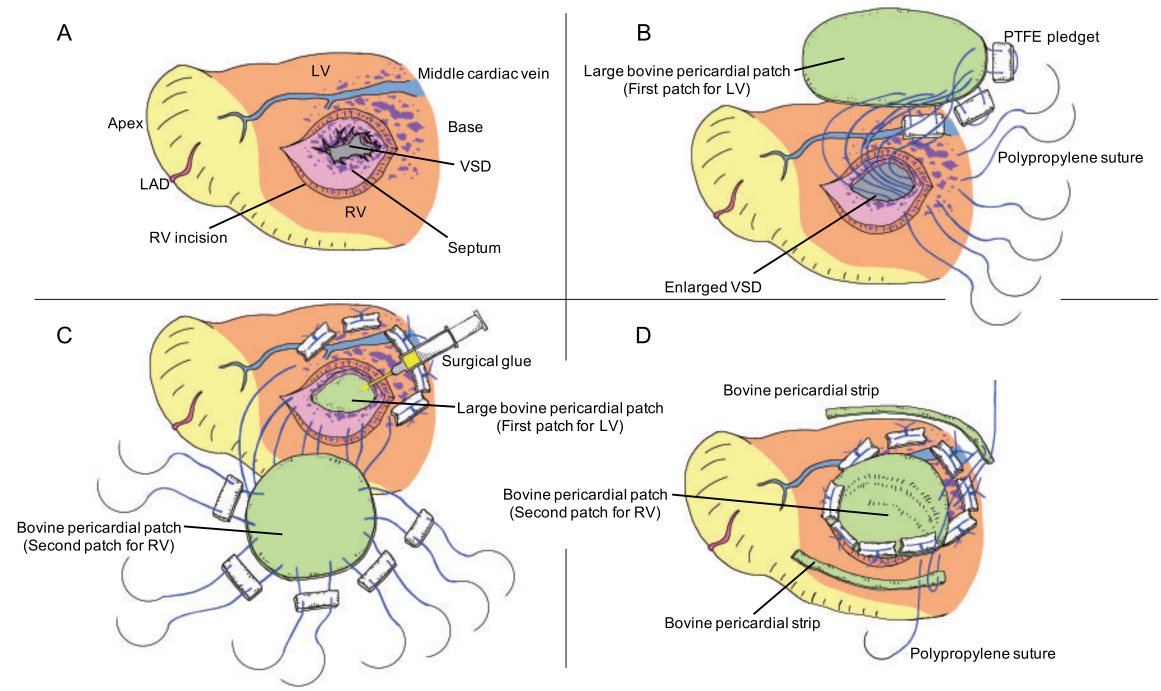

Figure 2 Sandwich patch ventricular septal defect repair *via* a right ventricular incision for extended posterior ventricular septal defect. A longitudinal right ventriculotomy was made along the posterior descending artery (*A*). A large first patch, with a long-axis length of 10 cm or more, was needed (*B*). The second patch covered the previous mattress sutures protruding out of the septum of the right ventricle side and the posterior descending artery-sided edge of the right ventricle (*C*). The right ventricular incision was suture-closed with the second patch and pericardial strips (*D*).

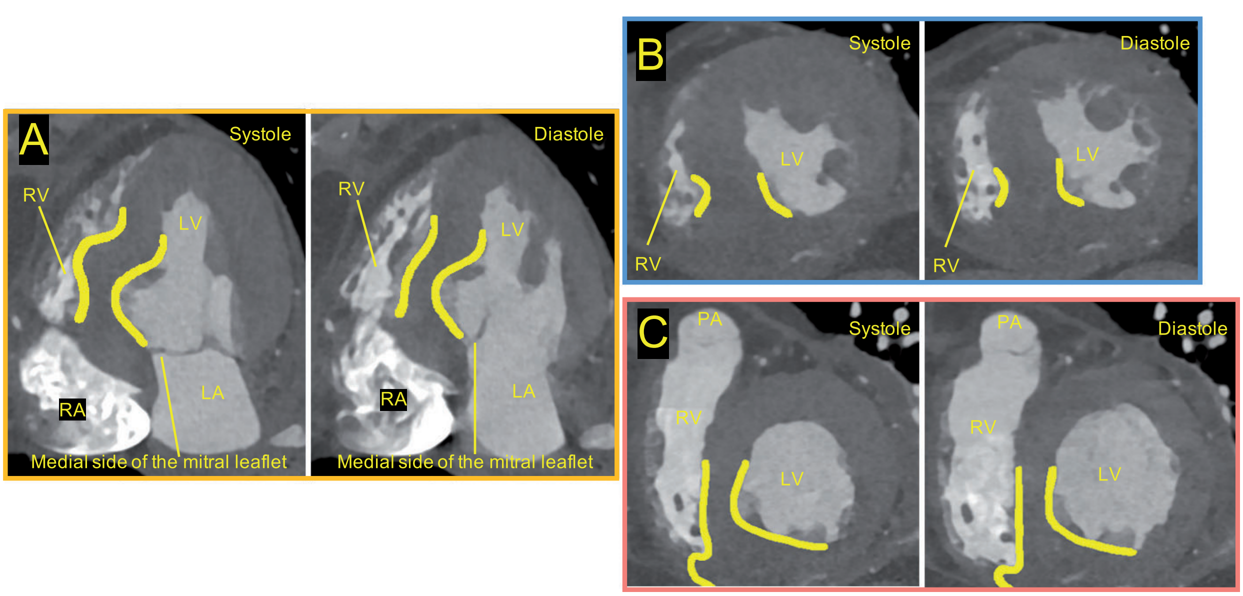

Figure 3 Computed tomography angiography 1 week after sandwich patch repair *via* a right ventricular incision for extended posterior ventricular septal defect (Patient 7). (*A*) Four-chamber views. (*B*) Short-axis views at the level of papillary muscles. (*C*) Short-axis views at the level of the tip of mitral leaflets. Thick yellow lines indicate bovine pericardial sandwich patches. LA, left atrium; LV, left ventricle; PA, pulmonary artery; RA, right atrium.

Table 1 Preoperative patients' characteristics

Patients	Age	Sex	STEMI region	STEMI culprit	Primary PCI	CAD	HT	DL	Diabetes	PVD	Comorbidity	frailty
1	82	F	Inferior	RCA	—	DVD	+	+	+	—	Spinocerebellar degeneration	+ (Wheel chair)
2	60	M	Antero-septum	LAD	—	SVD	+	—	—	—	—	—
3	69	F	Antero-septum	LAD	+	DVD	—	—	—	—	—	—
4	71	F	Antero-septum	LAD	+	TVD	+	+	+	—	Social withdrawal	—
5	85	M	Antero-septum	LAD	+	SVD	+	+	+	—	—	+ (Limited activity)
6	87	M	Antero-septum	LAD	—	TVD	+	+	+	+	ESRF (haemodialysis)	+ (Limited activity)
7	69	M	Inferior	RCA	+	SVD	+	+	—	—	—	—

CAD, coronary artery disease; DL, dyslipidaemia; DVD, double vessel disease; ESRF, end-stage renal failure; F, female; HT, hypertension; M, male; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; STEMI, ST-segment elevation myocardial infarction; SVD, single vessel disease; TVD, triple vessel disease.

Table 2 Preoperative major organ function

Patients	Cardiac (mechanical support)	Respiratory (intubation)	Central nervous system	Kidney (serum creatinine, mg/dL)	Liver (ALT > 500 U/L) or (TBil > 5.0 mg/dL)	Coagulation (platelets $< 100 \times 10^3/\mu L$)
1	IABP	—	—	2.1	—	—
2	IABP	+	Sedation	2.4	—	—
3	IABP	—	—	1.8	—	—
4	IABP	—	Confusion	1.9	—	—
5	ECMO Impella	+	Sedation	1.0	—	—
6	IABP	—	—	5.7 (HD)	—	—
7	IABP	—	—	1.1	—	—

ALT, alanine aminotransferase; ECMO, extracorporeal membrane oxygenation; HD, haemodialysis; IABP, intra-aortic balloon pump; TBil, total bilirubin.

Table 3 Surgery-related data

Patients	Surgical status	Projected interval (AMI to surgery) (days)	Interval (VSD diagnosis to surgery) (days)	VSD (location)	Concomitant procedure	Aortic cross-clamping time (min)
1	Emergency	2	0	Posterior	CABG x1	122
2	Emergency	6	0	Apical	LV rupture patch repair	90
3	Emergency	9	5	Apical	CABG x1	83
4	Emergency	1	0	Apical	CABG x3	126
5	Emergency	1	0	Apical	Impella discontinuation IABP initiation	124
6	Emergency	3	0	Anterior	CABG x2	115
7	Emergency	6	0	Posterior	—	174

AMI, acute myocardial infarction; CABG, coronary artery bypass grafting; IABP, intra-aortic balloon pump; LV, left ventricular; VSD, ventricular septal defect.

the LAD, the patient developed haemodynamic collapse due to pericardial tamponade caused by the postinfarction LV free wall rupture. Extracorporeal membrane oxygenation (ECMO) was immediately established, and emergency surgery was performed. Both the apical VSD and oozing rupture area in the anterior wall were covered by a large sandwich patch. The Impella was discontinued, and IABP was initiated during surgery. ECMO was discontinued 3 days postoperatively, and the postoperative course was uneventful without development of a residual shunt at follow-up after 1 year.

Table 4 **Postoperative results**

Patients	30-day death	Hospital death	Extubation (days)	IABPoff (days)	ECMO off (days)	Stroke	Length of hospital stay (days)	Follow-up period (years)	Cardiac event after discharge
1	—	—	5	6	NA	—	195	3	—
2	—	—	6	6	NA	—	74	3	—
3	—	—	1	6	NA	—	33	1	—
4	—	+	7	5	NA	+	52	NA	NA
5	—	—	5	5	3	—	117	1	—
6	—	—	4	5	NA	—	85	1	—
7	—	—	3	3	NA	—	17	0.5	—

ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; NA, not applicable.

Table 5 **Pre- and postoperative pulmonary artery catheter and transthoracic echocardiography assessment**

Patients	Period	Pulmonary artery catheter				Transthoracic echocardiography					
		Qp/Qs	RAP (mmHg)	Systolic PAP (mmHg)	CI (L/min/m^2)	LVDd (mm)	LVDs (mm)	LVEF (%)	MR	TR	Residual shunt
1	Pre	2.10	NA	30	1.5	40	25	55	≤Mild	≤Mild	
	Post	1.00	10	23	2.1	46	33	50	≤Mild	≤Mild	None
2	Pre	3.49	NA	45	NA	57	47	25	≤Mild	≤Mild	
	Post	1.00	12	20	2.6	43	37	33	≤Mild	≤Mild	Trace
3	Pre	3.90	NA	45	NA	55	45	35	≤Mild	Moderate	
	Post	0.90	7	24	2.7	57	47	25	Moderate	Moderate	4.0 mm
4	Pre	2.55	NA	32	3.0	40	35	35	≤Mild	Moderate	
	Post	0.96	10	27	2.5	37	26	46	≤Mild	≤Mild	Trace
5	Pre	4.60	NA	NA	NA	40	30	40	≤Mild	≤Mild	
	Post	1.10	NA	NA	NA	53	37	50	≤Mild	≤Mild	None
6	Pre	1.70	NA	24	1.6	50	42	20	≤Mild	≤Mild	
	Post	1.00	9	27	2.0	58	47	29	≤Mild	≤Mild	None
7	Pre	3.00	NA	44	5.3	55	37	55	≤Mild	≤Mild	
	Post	0.96	12	27	2.8	44	32	43	≤Mild	≤Mild	None

Postoperative Qp/Qs was calculated immediately after surgery. Postoperative RAP, systolic PAP, and CI were calculated 12 h after surgery. Transthoracic echocardiography was performed 1 week after surgery.
CI, cardiac index; LVDd, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; LVDs, left ventricular end-systolic diameter; MR, mitral regurgitation; NA, not applicable; PAP, pulmonary artery pressure; Qp/Qs, pulmonary to systemic blood flow ratio; RAP, right atrial pressure; TR, tricuspid regurgitation.

Patient 6

An 87-year-old male patient with haemodialysis-dependent renal failure was rushed to our hospital due to an anterior STEMI with a VSD. Emergency VSD repair with CABG to the posterolateral artery and PDA was performed. Postoperative course was uneventful, and no residual shunt developed 1 year postoperatively.

Patient 7

A 69-year-old male patient who suffered from chest pain for five consecutive days was emergency taken to our hospital due to worsening of the chest pain. The patient's diagnosis was an inferior STEMI, and emergency PCI was performed for the right coronary artery. IABP was subsequently initiated due to the ongoing preshock status. A VSD was detected by TTE, and emergency VSD repair was performed. We used a large oval bovine pericardial patch for the first patch because the ruptured septum extended along the long axis (*Figures 2 and 3*). The postoperative course was uneventful without development of a residual shunt at follow-up after 6 months.

Discussion

In the current study, a low hospital mortality rate after VSD repair at 14.3% (1/7) was noted despite the emergency and high-risk conditions. This was comparable to that of elective VSD repair reported in the Japanese National Database study (15.6% in elective surgery vs. 40.6% in emergency surgery; $P < 0.01$).[3]

Ventriculotomy-related complications

Sandwich patch VSD repair *via* an RV incision results in less damage to the left ventricle than VSD repair *via* an LV incision. Conventional infarct exclusion can potentially result in a significantly reduced LV function due to an oversized patch or damage caused by the left ventriculotomy. Furthermore, ventricular suture-line bleeding in the infarct left ventricle is a serious complication associated with hospital mortality.[3] In contrast, ventricular suture-line bleeding following the RV incision is not a common finding even in the acute phase of AMI, because the ischaemic damage to the RV myocardium is unlikely to occur as the oxygen demand is significantly lower in the right ventricle than in the left ventricle, the coronary perfusion in the right ventricle is obtained from the RV branch during both systole and diastole, and extensive collateral flows from the left coronary to the RV branch exist.[9,10]

We demonstrate several concerns regarding RV dysfunction after an RV incision; however, in the current study, the postoperative right atrial pressure was not significantly elevated at ≤12 mmHg, and we observed no early postoperative prolonged low cardiac output syndrome. Hosoba *et al.*[8] reported that the trivial RV dysfunction was detected in the early postoperative period and was not detected in the mid-term.

VSD repair without a ventriculotomy is an alternative procedure that prevents ventriculotomy-related complications. However, a transatrial approach is effective for limited VSD in the posterior septum and sometimes requires tricuspid valve replacement.[11] Although percutaneous VSD closure is another option, the hospital mortality rate is also high, at approximately 30%.[12]

Residual shunt following VSD repair in acute phase of AMI

A major residual shunt is likely to develop in the acute phase of AMI and is associated with hospital mortality. However, completely transmural mattress sutures with large PTFE pledgets allow surgeons to prevent myocardial cutting by the sutures and helps in the tight fixation of the sandwich patches on the myocardium, resulting in a lower incidence of major residual shunts and the prevention of any leak of the surgical glue into the ventricle. In the current study, although only one of the patients (14.3%) developed more than a trace residual shunt, the patient's postoperative haemodynamics remained stable, and no cardiac events developed 1 year postoperatively. Two studies that reported on a sandwich patch VSD repair *via* an RV incision[7,8] also reported a low incidence of major residual shunts (12% and 0%) with a mean interval of 2.1 days and 43 h from referral or onset of VSD to the surgery. These reports supported the decreased incidence of residual shunt development following sandwich patch repair in the early phase of AMI.

Delaying surgery

Delaying surgery works only in patients who are not frail and exhibit less haemodynamic instability, because this delay commonly requires a prolonged bedridden situation with multiple intravenous drugs, and mechanical circulatory and respiratory support. These conditions may result in systemic muscular depression, a worsened respiratory condition, increased susceptibility to infection, haemodynamic collapse, and significant major organ dysfunctions, all resulting in poor postoperative outcomes. Although an ECMO bridge to VSD repair may be a useful treatment in selected patients,[13] its efficacy remains unknown. Successful emergency VSD repair allows us to eliminate complications associated with delays in surgery.

Conclusions

In patients with postinfarction VSD, a sandwich patch VSD repair *via* an RV incision is a promising procedure with a low incidence of residual shunt development and hospital mortality, even in emergency cases.

Lead author biography

Yusuke Shimahara is a cardiovascular surgeon at National Cerebral and Cardiovascular Center, Osaka, Japan. He earned his PhD degree from Tohoku University in Sendai, Japan. He has a lot of expertise in cardiac surgery including off-pump coronary artery bypass surgery, valvular surgery, and transcatheter aortic valve replacement. His research interests include all arterial aortic no-touch off-pump coronary artery bypass surgery, hybrid off-pump coronary artery bypass surgery and transcatheter aortic valve replacement, surgical treatment of hypertrophic obstructive cardiomyopathy, and mitral valve surgery.

Supplementary material

Supplementary material is available at *European Heart Journal - Case Reports* online.

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that written consent for submission and publication of this case report including images and associated text has been obtained from the patients or family in line with COPE guidance.

Conflict of interest: None declared.

Funding: None declared.

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