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

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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 transesophageal 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
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. However, hospital mortality after surgical VSD repair was reported to be as high as 20–60%, especially in emergency cases. Recently, several authors have reported the efficacy of a sandwich patch VSD repair via a right ventricular (RV) incision. 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 large polytetrafluoroethylene (PTFE) pledgets 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 patients 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).

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.
## 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 transanctoracic echocardiography residual shunt, left ventricular ejection fraction |
|---------|-----|-----|---------------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------|-------------|---------------------------------|-----------------|------------------------------------------|----------------------------------------------------------------------------------|
| 1       | 82  | Female | 2                                                             | 0                                                           | Inferior                                   | IABP        | Coronary artery bypass grafting (CABG) x1 | None                                       | Postoperative day (POD) 5. Extubation                                            | None, 50%                                                         |
| 2       | 60  | Male | 6                                                             | 0                                                           | None                                       | Apical      | Left ventricular (LV) rupture repair      | IABP Ventilation | At 3 years. No cardiac event          | Trace, 33%                                                      |
| 3       | 69  | Female | 11                                                             | 6                                                           | Left anterior descending artery (LAD)      | Apical      | CABG x1                                   | None                                       | At 3 years. No cardiac event          | 4.0 mm, 25%                                                      |
| 4       | 71  | Female | 1                                                             | 1                                                           | LAD                                        | Apical      | CABG x3                                   | IABP            | At 1 year. No cardiac event          | Trace, 46%                                                      |
| 5       | 85  | Male | 1                                                             | 1                                                           | LAD                                        | Apical      | LV rupture repair, IABP insertion, Impella off | Extracorporeal membrane oxygenation (ECMO) Impella | None, 50%                                                         |
| 6       | 87  | Male | 3                                                             | 1                                                           | None                                       | Anterior    | CABG x2                                   | IABP            | None, 29%                                                               |
| 7       | 69  | Male | 6                                                             | 0                                                           | Right coronary artery                     | Inferior    | None                                       | IABP            | None, 43%                                                               |

Emergency sandwich patch repair via RV incision for postinfarction VSDs
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.
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.

| Patients | Age | Sex | STEMI region | STEMI culprit | Primary PCI | CAD | HT | DL | Diabetes | PVD | Comorbidity | frailty |
|----------|-----|-----|--------------|---------------|-------------|-----|-----|-----|----------|-----|-------------|--------|
| 1        | 82  | F   | Inferior     | RCA           | —           | DVD | +   | +   | —        | —   | —          | (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.

| 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 × 10^3/μL) |
|----------|-------------------------------|--------------------------|------------------------|-----------------------------------|-------------------------------------------|----------------------------------------|
| 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.

| 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 | 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.
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 following the infarct left ventricle is a serious complication associated with hospital mortality. In contrast, ventricular suture-line bleeding in the infarct exclusion can potentially result in a significantly reduced LV function.

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. 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. Although percutaneous VSD closure is another option, the hospital mortality rate is also high, at approximately 30%.

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 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, 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.

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