Review Article

Journal of Cardiovascular Medicine and Surgery
Volume 5 Number 4, October – December 2019
DOI: http://dx.doi.org/10.21088/jcms.2454.7123.5419.3

Left Ventricular Rupture after Mitral Valve Replacement: A Review of Etiopatholgy and Management

Sambhunath Das[1], Devishree Das[2]

Authors Affiliation: [1]Professor, [2]Senior Resident, Department of Cardiac Anaesthesia, Cardiothoracic Centre, All India Institute of Medical Sciences, Ansari Nagar, New Delhi 110029, India.

Abstract

Left ventricular rupture is a dreaded complication usually associated with myocardial infarction due to loss of myocardial integrity. Very few are linked with valve surgery. These are inherently unstable and unpredictable, therefore require early detection, prompt assessment and rapid management. Intraoperative transesophageal echocardiography plays a vital role not only for early detection but also for decision making regarding conservative management or surgical repair. The authors enumerate the clinical experience of 3 patients of left ventricular rupture following MVR and their prompt management. Here, we describe the review of left ventricular (LV) rupture after mitral valve replacement (MVR).

Keywords: Auto-transplantation; Left ventricular rupture; Mitral valve replacement; Transesophageal echocardiography.

How to cite this article:
Sambhunath Das, Devishree Das. Left Ventricular Rupture after Mitral Valve Replacement: A Review of Etiopatholgy and Management. J Cardiovasc Med Surg. 2019;5(4):173–181.

Introduction

Left ventricular (LV) rupture after mitral valve replacement (MVR) is rare but fatal complication which is responsible for 65–75% of mortality.[1] The incidence of LV rupture incidence is 0.5–2%.[1] Roberts and Morrow in 1967 first demonstrate LV rupture as one of the causes for early postoperative death following MVR.[2] Several risk factors responsible for LV rupture are elderly age >69 years, resection of basal chorda of the posterior leaflet, mitral annular reconstruction, severe calcification and left atrial plication.[3] Various surgical methods have been proposed to overcome the fatal condition which may include internal repair, external repair or combination of the both techniques. Anesthesiologists play a key role in early recognition of high risk patient, rapid detection by transesophageal echocardiography (TEE) and hemodynamic management for abrupt exsanguinating hemorrhage. The surgical decision to approach the LV rupture is essential component for postoperative outcome of the patient. We share and discuss our experiencein 3 cases of LV rupture following MVR. Literature review of LV

Corresponding Author: Dr. Sambhunath Das, Professor, Department of Cardiac Anaesthesia, Cardiothoracic Centre, All India Institute of Medical Sciences, Ansari Nagar, New Delhi 110029, India.

E-mail: dr_sambhu@yahoo.com

Received on 11.09.2019 **Accepted on** 23.10.2019

rupture after MVR is described with regards to the etiopathogenesis and management.

Clinical background

Case 1: A 36-years-old female patient with rheumatic mitral valve (MV) disease and persistent atrial fibrillation was referred for MVR. Echocardiography revealed severe mitral stenosis with mitral valve area 0.9 cm^2, mitral leaflets were thick and calcified with fibrosed subvalvular apparatus and the ejection fraction (EF) was 50%. There was no thrombus in left atrium and atrial appendage. An elective MVR was carried using 33 mm SJM (St. Jude Medical) bi-leaflet mechanical mitral valve. The initial aortic cross clamp (ACC) time and cardiopulmonary bypass (CPB) time was 40 min and 60 min respectively. After weaning from CPB severe ongoing blood loss was detected from the left side of the heart. Bleeding points were detected on the posterior aspect of left atrium and secured with multiple pledgeted sutures. Still the blood loss and hemodynamics could not be controlled despite rapid blood transfusion and higher inotropic and vasopressor support. Rapid CPB was instituted. The mechanical valve was explanted and the ruptured part of LV wall was sutured with Dacron patch support from the inner side of LV wall. After 44 min of ACC and 68 min of CPB patient was weaned with dopamine, dobutamine and noradrenaline support. The blood loss was less but persisted so sternum was kept open and shifted to ICU with cell saver for autologous blood transfusion. No further bleeding was detected and sternum was closed after 24 hours. Patient was extubated on 2nd postoperative day and the inotropic support gradually reduced. Patient was discharged from hospital on the postoperative day 12.

Case 2: A 43 years male patient was admitted with severe mitral regurgitation and persistent atrial fibrillation for elective MVR. On echocardiography MV prolapse with severe mitral regurgitation was detected with mild right ventricular dysfunction and EF was 50%. There was no thrombus in left atrium as well as in the atrial appendage. Surgery was performed using a SJM mechanical bi-leaflet valve of size 33 mm. After initial ACC of 33min and CPB of 52 min patient was weaned from CPB with higher inotropic support. Profuse bleeding was found from the postero-lateral wall of LV which could not be controlled with suturing. Patient hemodynamic was deteriorating regardless of excessive blood transfusion with elevated inotropic and vasopressor support. Immediate CPB was reinstituted, the mechanical valve was explanted, and LV rupture site was reinforced with pledgeted felt sutures. A small size mechanical mitral valve was placed (SJM size 29). After 123 min of ACC and 173 min of CPB patient was weaned off bypass for second time. Still bleeding continues for which CPB started for the third time. The bleeding points were assessed, sutured and roller gauze packs were placed at the site of bleeding. The third time ACC and CPB duration was 51 and 83 min respectively. Sternum was kept open and shifted to ICU with dopamine, dobutamine, noradrenaline and adrenaline support. After 36 h sternum was closed and patient was extubated on 4th postoperative day. The hospital length of stay was 21 days. In this case blood bank plays a key role in providing adequate amount of blood and blood products in short span of time.

Case 3: Another patient of rheumatic mitral valve disease operated for MVR. He had undergone closed mitral valvotomy 5 years before. The echocardiography showed thickened leaflets with calcified annulus, severe mitral stenosis with severe tricuspid regurgitations. Patient had persistent atrial fibrillation with control ventricular rate and ascites. Patient underwent MVR and TV repair. After 145 min of ACC and 290 min of CPB, patient was weaned with higher support of adrenaline, noradrenaline, and vasopressin. Postoperatively the bleeding started from posterior side of LV wall with extensive rupture. Second time, CPB was not attempted because of very poor ventricular function. The bleeding couldn't be controlled by all surgical and medical methods as mentioned above 2 cases. The patient required high inotropes and IABP. Large numbers of blood and products transfusions were given. Unfortunately, the patient died on 5th postoperative day from LV failure.

All the 3 patients inspired us to write this review to have a better understanding of the causes for LV rupture after MVR and how to manage for satisfactory outcome. There is paucity of study and review paper on the topic; rather some case reports are available in literature. The different approach to the situation with no established consensus for treatment requires a thorough review.

Methodology of Review

The review was planned after collecting all the literatures in the last 18 years from January 2001 to June 2019. Pub Med search was performed with

the key words 'Left Ventricle rupture, after mitral valve replacement' and the filters were case reports, clinical trial, controlled trial, randomized control trial, multi-centric study, observational study and validation study. Total 124 articles were collected. Restricting to only LV rupture after post-surgery mitral valve replacement, we finalized with 38 articles **Table 1**.

Table 1: Summary of the Published Papers

Authors	Study type	Diagnosis	Type of LVR	Management method	Outcome
AntonicM *et al.*[3]	Case report	MS + MR	Type I	bovine pericardial patch repaired	Patient survived
Ni B *et al.*[4]	Report	MS+ MR	Type I	Auto-transplantation	survived
Schneider YA[5]	Review	–	–	–	–
Komagamine M *et al.*[6]	case report	AS	Type II	MVR	survived
Hata H *et al.*[7]	Case report	MR with abscess	Type I	Auto-transplantation by staged approach	survived
Costa MA *et al.*[8]	Case report	MS + mild MR	Type I	bovine pericardium with suture less glue	survived
Brassard CL[9]	Report	MR	Type III	Smaller size valve	Died
Nishida H *et al.*[10]	Case report	MS	Type III	patch using the felt sandwich technique	survived
Lee JH *et al.*[11]	Case report	MS, AR	Aneurysm Type I	Supple pericardium patch using pledgeted suture	survived
Argiriou M[12]	Report	MR, AS	Type IV	Extensive rupture, Could not repair	Died
Lee ME *et al.*[13]	Case report	MS	Type III + IV	Plug of Teflon felt into the cavity and sandwiching with pledgeted mattress suture	survived
Kwon JT[14]	Report	MS, AR, TR	Type IV	bovine pericardial patch	survived
Ikegami H *et al.*[15]	Case report	Redo MVR	Pseudoaneurysm- I	multiple interrupted pledgeted sutures,	survived
SahebjamM *et al.*[16]	Case report	Post CABG and MVR	Pseudoaneurysm- I	pericardial patch	survived
Liao JN *et al.*[17]	Case report	MS	Pseudoaneurysm- I	Close follow up	survived
Suzuki R *et al.*[18]	Case report	Post MVR	Type IV	pledgeted mattress sutures and fibrin glue	survived
Goldstone Ab *et al.*[19]	Case report	Redo MVR	Type I+ IV	Modified Cabrol shunt	survived
Sersar SI *et al.*[20]	Report	Redo MVR	Type V	Repair	Died
Biyikoglu SF *et al.*[21]	Case report	Post MVR & CABG	Pseudoaneurysm	Dacron patch pledgeted sutures	survived
Park CK *et al.*[22]	Report	MS with AF	Type IV	pericardial patch and pledgeted suture	survived
Garcia-V OA *et al.*[23]	Case report	MVR	Type IV	Fibrin sealant with external Teflon-pledgeted sutures.	survived
Lanjewar C[24]	Report	Post MVR	Type IV	woven Dacron fabric patch sutured	survived
Digonnet A[25]	Report	Post MVR	Type IV	internal and external approach	survived
Nishimura Y *et al.*[26]	Case report	Post MVR acute MI	pseudoaneurysm	patch repair of the orifice of the pseudoaneurysm	survived
Kamada M[27]	report	PTMC/MVR	Type III	Sutured and small size valve placed	survived
Terada H *et al.*[28]	report	Post MVR	Delayed-I	Intracardiac and extracardiac repair	survived

Authors	Study type	Diagnosis	Type of LVR	Management method	Outcome
Yaku H *et al.*[29]	Case report	Post MVR	Type I	Mattress stitches buttressed with strips of Dacron felt, constructed a new annulus with bovine pericardium	survived with foot drop
Tanaka K[30]	Report	Degenerative	Type I	Repaired from outside the heart	survived
Masroor S *et al.*[31]	Case report	Calcified MS + ASD	Type I	pericardial patch, Teflon felt and BioGlue	survived
Fasol R *et al.*[32]	Case report	Rheumatic MS	Type III	combination of a Teflon patch suture and sealant	survived
Mihaljevic T[33]	Report	MR	Type I	Pericardial patch	survived
Dübel HP *et al.*[34]	Case report	Postop MVR	Pseudoaneurysm	Rupture of LV prior to surgery	Died
Abid Q *et al*[35]	Report	MVR	Type I	repaired by pledgeted stitches-IABP	survived
Cheikhaoui Y *et al*[36]	Case report	MS-1 and MR-2	Type III-1 Type IV-2	1st- horizontal mattress sutures through felt strips 2nd- intra-ventricular patch	survived
Yoshikai M *et al.*[37]	Case report	MS with calcification	Type I	Autologous pericardium was secured to the LV posterior and atrial wall for annular reconstruction	survived
Gomes WJ[38]	Report	Severe MR	Delayed-I	Intraventricular repair	survived
Wei J *et al.*[39]	Report	MR/ MS	Type II	Autotransplant in both cases	survived
Tayama E *et al*[40]	Case report	MS	Type I	Intracardiacpatch and an extracardiac buttress suture	survived

(*Abbreviations*: LVR- left ventricle rupture, MS- mitral stenosis, MR- mitral regurgitation, AS- aortic stenosis, AR- aortic regurgitation, TR- tricuspid regurgitation, CABG- coronary artery bypass grafting, MVR- mitral valve replacement, LV- left ventricle, IABP- intra aortic balloon pump, PTMC- percutaneous transvenous mitral commissurotomy)

We described all the details about the etiopatholgy of LV rupture, the different strategies of management and how to have early diagnosis and prompt management for better outcome.

Etio-pathogenesis

After the replacement of mitral valve LV rupture can be due to inappropriate selection of prosthetic heart valve especially in elderly or female patients having little fibrous annulus. If the prosthesis is bigger than annulus, local ischemia and stretching may occur as the prosthesis compress mitral ring, causing wall akinesia. This akinetic segment protrudes during systole, leading to myocardial fibers stretching along with the vascular lesions. As a result hematoma could be formed and may result in an immediate rupture. Later it may devolve to ventricular dysfunction or even aneurysm. Ischemic heart is flaccid which frequently cause perforation of ventricular wall near papillary muscle while removing the diseased valve. Intraoperative hypertension or increased myocardial contractility due to high inotropes may be one of the predisposing factors.

Based on autopsy finding of 7 cases, Cobbs BW *et al.*[40] proposed "untethered loop" hypothesis. According to the hypothesis a loop is formed by the supporting structure of posterior ventricular wall where longitudinal muscle forms the outer portion and papillary muscle with cordae attaching to annulus of mural leaflet constitutes the inner portion. Therefore, the posterior ventricular wall was weakened by division of mural leaflet chordae.

The decalcification valve at the annulus and posterior part are at risk for rupture.[31,37] The LV wall may get damaged while removing the calcium from mitral valve apparatus. Degenerative mitral valves also prone for rupture due to lack of healthy tissue.[30] Larger MV annulus has thinner wall that increases the chance of rupture. Redo MVR cases are at risk of rupture because the removal of adhesions during dissection may injure the AV groove and or LV wall.[15,19,20] Excessive resection of leaflet, chordate and supporting structures predispose to injure the LV wall in many patients.

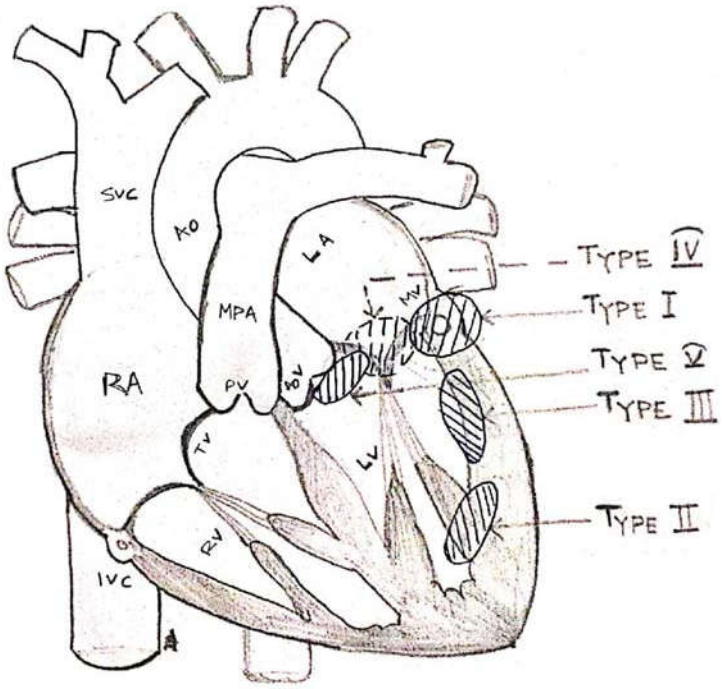

Fig. 1: Schematic diagram of heart showing 5 different sites of LV rupture after MVR.

(Abbreviations: LV-left ventricle, LA- left atrium, RV- right ventricle, RA- right atrium, MV- mitral valve, TV- tricuspid valve, AoV-aortic valve, Ao-aorta, MPA-main pulmonary artery, PV- pulmonary valve, SVC- superior vena cava, IVC-inferior vena cava).

Thickened ventricular myocardium in associated aortic valve disease especially in aortic stenosis resistant for rupture and may have protective effect. The various complications after MVR include para-valvular leaks, rhythm abnormalities, hemorrhage, thrombo-embolisms, valvular degeneration and endocarditis. Most devastating one is exsanguinating hemorrhage following LV wall rupture. Originally LV rupture is classified into 3 categories (**Fig. 1**).

Table 2: Classification of LV wall rupture

Type 1	Rupture at the posterior atrioventricular groove
Type 2	Rupture at the base of the papillary muscle
Type 3	Rupture between AV groove and papillary muscle
Type 4	Rupture of the lateral wall
Type 5	Rupture of the LV outflow tract

Sersar SI and Jamjoom AA[42] added further 2 Types i.e. Type 4 and Type 5 (Table 1). Type 1 is most common and associated with maximum mortality. Some reports also specifically detected the LV rupture at posterior wall.[36]

On the basis of evolution LV rupture can be early, delayed and late onset. Early lethal event can occur during surgery before or after weaning from CPB in MVR patients. Delayed rupture develops hours to days after MVR. Late tears appear after few days to years and usually manifest as LV pseudo-aneurysms (LVPA).[42]

Diagnosis

1. *Clinical:* The main clinical manifestations include unstable hemodynamics after weaning from CPB, profuse bleeding near LV or through chest tubes, arrhythmias and sudden hypotension. Patient may present with LV failure with dissecting hematoma while delayed type presents with pseudoaneurysm. LV pseudo aneurysm sac may be too large to compress left circumflex artery producing myocardial infarction. It may cause LV failure, thrombus formation and embolization, even sudden rupture and death. Spellberg and O'Reilly reported two cases of false ventricular aneurysm following MVR which presents with pansystolic murmur with or without mitral regurgitation.[43]
2. *Echocardiography:* Preoperative transthoracic echocardiography reveals valvular or annular calcification, fusion of subvalvular apparatus;

small ventricular cavity and mitral annular abscess are categorized as high risk case. Air in the LV cavity is the pathognomic sign of LV rupture detected by intraoperative transesophageal echocardiography.[9] Hematoma can be seen underlying inferior wall and associated LV dysfunction with regional wall motion abnormalities may be detected. Color Doppler shows blood flow across the orifice of LVPA. Contrast enhanced echocardiography may be useful to diagnose the LV free wall rupture after MVR.[44]

3. *Others:* In LVPA, chest X-ray shows bulging around the left cardiac border on. Left ventriculography demonstrates a dome shaped extravasation along the postero-lateral wall of LV. Computed Tomography (CT) scan and cardiac MRI with contrast is useful for better understanding of spatial relationship and distinguishing true aneurysm from pseudoaneurysm.[45]

Management

Preventive measures: Prevention and precautions are most important to avoid this fatal complication as mentioned in **Table 3**.

Table 3: Preventive methods of LV rupture

1.	Avoid bigger prosthetic valve
2.	Calcified and degenerative cusp and annulus to be dissected meticulously
3.	Cordal preservation
4.	Optimum retraction at annulus, LV wall in ischemic and redo surgery
5.	Avoidance of LV vents
6.	Avoidance of lifting the heart after prosthetic valve implantation[42]
7.	Use of translucent obturator for visualization of the posterior aspect prior to the prosthetic valve insertion[42]
8.	In depth analysis of ECHO, chest X-ray, CT scan and MRI preoperatively is advisable especially in redo surgeries[42]

Resuscitation: The role of anesthesiologist is not only maintaining hemodynamics but also prompt detection by TEE and helps in decision making for treatment. Hemodynamics has to be maintained with rapid blood administration to optimize hematocrit and blood volume and judicious use of inotropes and vasopressor. Here we have used cell salvage technique for autotransfusion where continuously blood from the draining site was collected and retransfused to the patient after filtration. It helps to preserve the essential blood components, reduces allogenic blood supplies and eliminates transfusion associated infection and reactions.

Surgical management: Surgeon has to avoid dissecting out excess calcium from posterior ring as the posterior part has less fibrous tissue than anterior site and is therefore susceptible to rupture. Conservative strategies are recommended for AV groove hematoma till hemodynamic instability as redo-surgeries are associated with higher mortality. The challenge in exposure of the tear is due to anatomical vulnerability of the left circumflex artery.

Numerous surgical techniques have been described out of which "internal" repair approach is most commonly recommended and consists of prosthesis explantation and tear repair with a patch positioned from within the cardiac cavity.[15]

Costa MA, *et al.*[8] developed an innovating technique where a flap of bovine pericardium was immediately fixed with N-butyl-2 cyanoacrylate and methacryloxysulfolane over the area of bleeding, filling the retrocardiac space with absorbable gelatin sponge for compression, where the sutures were not used.

B Ni *et al*.[4] successfully opted sandwich style repair and auto-transplantation. Here cardiectomy was carried out by serial transections of all great vessels leaving the left atrial cuff. Myocardial protection was achieved with histidine-tryptophan ketoglutarate cardioplegia and rupture was repaired with 3–0 Prolene-interrupted mattress sutures in sandwich style, placing autologous pericardial patch and stripes of Teflon felt at the endocardial and epicardial surface of the left ventricle. The repaired heart was reimplanted by bicaval technique.

Other techniques of surgical repair includes off-pump technique with Teflon patch and glue, off-pump with epicardial tissue sealing, use of intracardiac patch and extracardiac buttress suture, endo-ventricular pocket repair using pericardial patch, Teflon felt, and BioGlue, Partial translocation technique and repair by patch and sealing on CPB and cardioplegia.[13,22,23]

Intraoperative decision-making regarding conservative management versus additional surgical repair require through understanding pathophysiology and integrating partial findings from complementary viewpoints. The surgeon and anesthesiologist should work as a team for accurately assessing the intense situation and

develop a common notion.

Medical measures: Topical sealants to stop diffuse bleeding over the rupture area after surgical procedure. Many types of tissue sealants are available. These are Bio glue, surgiseal, gel foam, Thrombin sealants, Fibrin glue, Gelatin matrix and Thrombin.[23,31] Transfusion of platelet concentrate, cryo precipitate, fresh frozen plasma are occasional effective in consumption coagulopathy situation to promote coagulation. Some repeat dose of protamine may benefit in patients with higher activated clotting time. Antifibrinolytics like epsilon amino caproic acid and tranexamic acid are effective to check bleeding due to fibrinolysis.

Strict observation: Situations like hematoma formation, diffuse bleeding and minimal bleeding from the suspected rupture sites are left with wait and watch conservative method with packing, local sealants and sternum open. Gradually the tissue edema subsides, improvement in vascularity and tissue became healthy; subsequently the surgical intervention may not require on close follow up.[17]

Postoperative in ICU: patient may require prompt attention and careful hemodynamic management in early postoperative period. Early arrangement of blood and institution of cell saver may be opted for managing the ongoing blood loss. Patient may require prolong ventilation and therefore proper care to be taken to avoid ventilator associated co-morbidities. As hospital length of stay is more infection control to be prioritized.

Conclusion

Rupture of LV wall after MVR is a rare but fatal complication. Operative trauma and coexisting fragile myocardium precipitates the condition. Anesthesiologist not only helps in early detection with intra-operative TEE examination but also maintain hemodynamic. Use of judicious inotropes in order to avoid acute hypertension and vigorous myocardial contraction is important consideration. Immediate resuscitation, reinstitution of CPB and successful repair of the tear require a team effort. Understanding the etiopathogenesis will help to prevent the development of rupture of LV wall. Prompt surgical decision to repair by adopting the suitable possible technique from many methods is lifesaving.

Acknowledgement: Nil

References

1. Roberts WC, Morrow AG. Cause of early postoperative death following cardiac valve replacement. J Thorac Cardiovasc Surg. 1967;54:422.
2. Zacharias A, Groves LK, Cheanvechai C *et al*. Rupture of the posterior wall of the left ventricle after mitral valve replacement. J Thorac Cardiovasc Surg. 1975;69:259–63.
3. Antonic M, Djordjevic A, Mohorko T, *et al*. Left ventricular pseudoaneurysm following atrioventricular groove rupture after mitral valvereplacement. SAGE Open Med Case Rep. 2019;12;7:1–4.
4. Ni B, Zheng X, Zhang S, *et al*. Cardiac autotransplantation for repair of left ventricular rupture after mitral valve replacement. Interact Cardiovasc Thorac Surg. 2017;25:150–52.
5. Schneider YA, Tsoi MD, Antipov GN *et al*. Experience of treatment of spontaneous rupture of left ventricular posterior wall after mitral valve replacement. Kardiologiia. 2017;57:85–90.
6. Komagamine M, Furukawa N, Gummert J, *et al*. Posterior papillary muscle rupture after transapical transcatheter aortic valve implantation. Eur J Cardiothorac Surg. 2018;54:596–97.
7. Hata H, Shiono M, Iida M, *et al*. Autotransplantation for threatened cardiac rupture after left ventricular repair. Ann Thorac Surg. 2017;103(2):e163–e165.
8. Costa MA, Laforga FC, Maftum JA, *et al*. Use of Bovine Pericardium and Sutureless Biological Glue in Left Ventricular Rupture After Mitral Valve Replacement, Five Years of Follow-up. Braz J Cardiovasc Surg. 2015;30:673–5.
9. Brassard CL, Viens C, Denault A, *et al*. Transesophageal echocardiographic imaging of multiple complications following mitral valve replacement. Echo Res Pract. 2015;2:K37–41.
10. Nishida H, Fukui T, Kin H, *et al*. Asymptomatic Regional Thinning of Left Ventricle After Mitral Valve Replacement. Ann Thorac Surg. 2015;100:1896–8.
11. Lee JH, Jeon SC, Jang HJ, *et al*. Left ventricular pseudoaneurysm after valve replacement. KoreanJThoracCardiovasc Surg. 2015;48:63–6.
12. Argiriou M, Patris V, Lama N, *et al*. Left ventricular rupture after double valve replacement in a patient with myocarditis due to myasthenia gravis: case report. Cardiovasc J Afr. 2013;24:e5–7.
13. Lee ME, Tamboli M, Lee AW. Use of a sandwich technique to repair a left ventricular rupture after mitral valve replacement. Tex Heart Inst J. 20141;41:195–7.
14. Kwon JT, Jung TE, Lee DH. The rupture of atrioventricular groove after mitral valve replacement in an elderly patient. J Cardio thorac

Surg. 2014;9:28.

15. Ikegami H, McCarthy PM. Internal repair of left ventricular pseudoaneurysm late after mitral valve replacement. Interact CardiovascThorac Surg. 2014;18:128–9.
16. Sahebjam M, Salehiomran A, Ghaffari-Marandi N, *et al*. Late diagnosis of large left ventricular pseudoaneurysm after mitral valve replacement and coronary artery bypass surgery by real-time three-dimensional echocardiography. J Tehran Heart Cent. 2012;7(4):188–90.
17. Liao JN, Huang CH, Wu MH, *et al*. Pseudo-mitral regurgitation 20 years after mitral valve replacement: a subannular left ventricular pseudoaneurysm with rupture into the left atrium. Eur Heart J. 2012;33: 2497.
18. Suzuki R, Mikamo A, Kurazumi H, *et al*. Left ventricular free wall rupture detected by multidetector computed tomography after mitral valve replacement. J Card Surg. 2010;25:699.
19. Goldstone AB, Chikwe J, Stelzer P. Modified Cabrol shunt to treat left ventricular rupture. Ann Thorac Surg. 2010;89:313–4.
20. Sersar SI, Bassiouni AM, Jamjoom AA. New type of left ventricular rupture during redo mitral valve replacement. A case report. HSR Proc Intensive Care Cardiovasc Anesth. 2009;1:44–6.
21. Biyikoglu SF, Guray Y, Turkvatan A, *et al*. A serious complication late after mitral valve replacement: left ventricular rupture with pseudoaneurysm. J Am SocEchocardiogr. 2008;21(10):1178.e1–3.
22. Park CK, Park PW, Yang JH, *et al*. Intraventricular patch repair through an extended aortotomy for repeated left ventricular rupture after mitral valve replacement. AnnThorac Surg. 2008;86:1000–2.
23. Garcia-Villarreal OA, Casillas-Covarrubias LE. Fibrin sealant for left ventricular rupture after mitral valve replacement. Asian Cardiovasc Thorac Ann. 2008;16:152–3.
24. Lanjewar C, Thakkar B, Kerkar P, *et al*. Submitral left ventricular pseudoaneurysm after mitral valve replacement: early diagnosis and successful repair. InteractCardiovascThorac Surg. 2007;6:505–7.
25. Digonnet A, Flecher E, Aubert S, PavieA. Successful repair of late left ventricular rupture after mitral valve replacement. J Heart Valve Dis. 2007:16:136–8.
26. Nishimura Y, Okamura Y, Noguchi Y, *et al*. Successful repair of a large pseudoaneurysm of the left ventricle late after mitral valvereplacement due to rupture of the papillary muscle following acute myocardial infarction. Ann Thorac Cardiovasc Surg. 2004;10:386–8.
27. Kamada M, Ohsaka K, Nagamine S, *et al*. Left ventricular rupture following mitral valve replacement due to oversize prosthesis. Jpn J Thorac Cardiovasc Surg. 2004;52:589–91.
28. Terada H, Kazui T, Yamashita K, *et al*. Repair of delayed left ventricular rupture after mitral valve replacement: report of a case. Surg Today. 2004;34:958–60.
29. Yaku H, Shimada Y, Yamada Y, *et al*. Partial translocation for repair of left ventricular rupture after mitral valve replacement. Ann Thorac Surg. 2004;78:1851–3.
30. Tanaka K, Mashiko K, Kawada N. [Successful repair of the left ventricular wall rupture after mitral valve replacement of an octogenarian; report of a case]. Kyobu Geka. 2004;57(9):885–8.
31. Masroor S, Schor J, Carrillo R, *et al*. Endoventricular pocket repair of Type I myocardial rupture after mitral valve replacement: A new technique using pericardial patch, Teflon felt, and BioGlue. Ann Thorac Surg. 2004 Apr;77:1439–41.
32. Fasol R, Wild T, El Dsoki S. Left ventricular rupture after mitral surgery: repair by patch and sealing. Ann Thorac Surg. 2004;77(3):1070–2.
33. Mihaljevic T, Couper GS, Byrne JG, *et al*. Echocardiographic localization of left ventricular free wall rupture after minimally invasive mitral valve replacement. J Cardiothorac Vasc Anesth. 2003;17:733–5.
34. Dübel HP, Gliech V, Borges AC, *et al*. Left ventricular pseudoaneurysm after mitral valve replacement. ZKardiol. 2003;92:953–6.
35. Abid Q, Rao PS, Kendall SW. Use of intraaortic balloon pump in left ventricle rupture after mitral valve replacement. Ann Thorac Surg. 2002;74:2194–5.
36. Cheikhaoui Y, Amahzoune B, Oukerraj *et al*. Ruptures of the posterior wall of the left ventricle after mitral valve replacement: surgical repair and prevention. Ann Cardiol Angeiol (Paris). 2001;50:146–50.
37. Yoshikai M, Ito T, Murayama J, *et al*. Mitral annular reconstruction. Asian Cardiovasc Thorac Ann. 2002;10:344–5.
38. Gomes WJ, Underwood M, Ascione R, *et al*. Treatment of delayed rupture of the left ventricle after mitral valve replacement. Arq Bras Cardiol. 2002;79:544–9.
39. Wei J, Wu C, Hong G, *et al*. Auto-transplantation of heart for repair of left ventricular rupture after mitral valve replacement. Transplant Proc. 2001;33:3553-4.
40. Tayama E, Akashi H, Hayashida N *et al*. Repair of left ventricular rupture following mitral valve replacement concomitant with left atrial reduction procedure-intracardiac patch and extracardiac buttress suture. Jpn Circ J. 2001; 65:581-3.
41. Cobbs BW, Hatcher CR Jr, Craver JM, *et al*. Transverse midventricular disruption after mitral valve replacement. Am Heart J. 1980 Jan;99(1):33-50.
42. Sersar SI, Jamjoom AA. Left ventricular rupture post mitral valve replacement. Clin Med Cardiol. 2009;3:101–113.

43. Spellberg, RD and O'Reilly, RJ. Pseudoaneurysm of the left ventricle following mitral valve replacement. Chest. 1972;62:115.

44. Okabe T, Julien HM, Kaliyadan AG, *et al*. Prompt Recognition of Left Ventricular Free-Wall Rupture Aided by the Use of Contrast Echocardiography. Tex Heart Inst J. 2015;42:474–478.

45. Hulten EA, Blankstein R. Pseudoaneurysm of heart. Circulation. 2012;125:1920–25.