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CASE SERIES
Heart failure

Utilization of intra-aortic balloon pump to allow MitraClip procedure in patients with non-coapting mitral valve leaflets: a case series

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Background The MitraClip (MC) procedure was designed for high-risk surgical patients with severe mitral regurgitation (MR). Some patients do not meet the required anatomical criteria due to advanced left ventricular remodelling and mitral annular dilatation leading to leaflet tethering and insufficient coaptation surface. Theoretically, 'temporary remodelling' of the mitral valve apparatus by pharmacological and/or mechanical support using intra-aortic balloon pump (IABP) could improve leaflets coaptation.

Case summary We report a case series of four patients with severe MR and non-coapting leaflets who underwent MC implantation. Sufficient coaptation was achieved only after insertion of IABP. The first patient presented with worsening heart failure and severe MR after a non-reperfused posterior wall myocardial infarction (MI), underwent a successful procedure with good results. The second patient presented with worsening heart failure secondary to rheumatic MR, and underwent MC procedure with good results after the insertion of IABP. The third patient developed worsening heart failure and severe MR 2 months after an acute inferior-lateral MI, and underwent a successful procedure. The fourth patient presented with respiratory failure, the patient underwent the procedure, but unfortunately died a few days following the procedure from multiorgan failure. In each case, the insertion of the IABP decreased annular mitral diameter and increased the coaptation surface as assessed by transoesophageal echocardiography.

Discussion For patients suffering from symptomatic severe MR who are not suitable candidates for MC procedure, IABP system enabled us to overcome mitral leaflet gap and complete the MC procedure successfully.

Keywords Case series • Mitral regurgitation • Edge-to-edge mitral valve repair • MitraClip • Intra-aortic balloon pump

Learning points

- Intra-aortic balloon pump (IABP) insertion might allow MitraClip (MC) procedure in patients with non-coapting mitral valve leaflets.
- The use of IABP in dilated/functional mitral regurgitation might allow better leaflet coaptation via reduction in mitral annular diameter and increase in leaflet coaptation surface.
- Use of IABP to improve objective parameters, such as left ventricle geometry and mitral valve configuration, allows technically feasibility and success of MC procedure by better leaflet coaptation and optimization of MC procedure.

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Introduction

The MitraClip (MC) device (Abbott Laboratories, Abbott Park, IL, USA) is a transvenous, edge-to-edge repair system for high-risk surgical patients with severe mitral regurgitation (MR).[1,2] To guarantee the safe positioning of the MC, anatomical eligibility criteria are recommended: a coaptation length of valve leaflets ≥2 mm, depth of <11 mm, and in the case of degenerative disease, a flail gap of <10 mm, and a flail width of <15 mm are favourable.[3] A sufficient coaptation surface length is an important anatomical criterion, which precludes some patients from the procedure.

Theoretically, the coaptation surface length might be altered by pharmacological or mechanical support. Intra-aortic balloon pump (IABP) is the most widely used circulatory assist device in critically ill patients with cardiac disease.[4] Counterpulsation (i.e. balloon inflation in diastole and deflation in early systole) decreases pre- and afterload thus reducing myocardial oxygen consumption, left ventricle (LV) wall tension, and systolic pressure, and increasing diastolic pressure. These effects might allow a 'temporary remodelling' of the mitral valve apparatus, which could improve coaptation.[5] There are only few reports on the use of the IABP system in patients presenting in cardiogenic shock and require mitral valve intervention.[6] Nevertheless the use of IABP system for 'non suitable' anatomical MR cases as means of allowing better leaflet coaptation is even more limited. We have screened a cohort of 80 patients who underwent MC implantation at the Hadassah Medical Center between August 2015 and April 2018. Of these patients, we selected four patients with non-coapting (i.e. 'wide open'/'free') MR. In these patients, IABP was inserted prior to the MC procedure as a means of allowing better leaflet coaptation as assessed by transoesophageal echocardiography (TOE).

Timeline

Patient 1	
	6 January 2018: Inferior-posterior wall ST-elevation myocardial infarction (STEMI), underwent percutaneous coronary intervention (PCI) to left circumflex (LCX) artery, cardiogenic shock, pulmonary oedema, and intra-aortic balloon pump (IABP) insertion
	7 January 2018: Transthoracic echocardiography (TTE) mildly dilated left ventricle (LV) with moderately reduced global systolic function, moderately dilated left atrium (LA), and mitral valve (MV): apical tethering of the leaflets causing incomplete closure and severe regurgitation. Moderately elevated pulmonary systolic pressure 50 mmHg.
	31 January 2018: Patient discharged after weaning off IABP and optimal medical therapy for congestive heart failure (CHF)
	10 February 2018: Admission for urinary tract infection, develops pulmonary oedema and worsening CHF
	14 February 2018: TTE-dilated LV with moderate-severely reduced systolic function, severe mitral regurgitation (MR) with non-coapting MV leaflets
	19 February 2018: IABP insertion
	21 February 2018: MitraClip (MC) procedure after transoesophageal echocardiography (TOE) confirming severe MR with adequate coaptation surface
	12 March 2018: CHF symptom improvement on oral medical therapy, discharged home
	20 June 2018: Patient in New York Heart Association (NYHA) Class II and has not had any hospitalizations for heart failure. Mild MR on TTE
Patient 2	
	27 March 2018: Admission for worsening CHF, pulmonary oedema, and rapidly conducted atrial fibrillation

Continued

Case presentation

Patient 1

Patient information

A 69-year-old female patient with a prior history of hypertension, diabetes, hyperlipidaemia, and ischaemic heart disease, who suffered a recent non-reperfused posterior wall myocardial infarction (MI). Transthoracic echocardiography (TTE) showed mildly decreased LV systolic function [LV ejection fraction (EF) 45–50%], moderately dilated left atrium, severe MR with apically tethered leaflets, other causes for decompensation, and murmur including ventricular septal defect (VSD)/papillary muscle rupture, etc. were excluded. She continued suffering from congestive heart failure (CHF) symptoms: rest dyspnoea, no physical capacity, diuretic dependence, and pulmonary congestion.

Physical examination

On examination, she was with severe respiratory distress, her respiratory rate was 30 breaths/min, and her lung examination was suggestive for pulmonary oedema, heart sounds were rapid and a harsh pansystolic murmur was audible.

Interventions

Although the patient was not an optimal candidate for MC and in this effort, an IABP was inserted and left *in situ* for 24 h in order to optimize haemodynamic status, with the aim of altering LV geometry and to optimize the chances of success of MC by improving the coaptation length. On TOE, the baseline average annular diameter calculated in two orthogonal views, namely the mitral commissural (MC) and long axis was 37 mm. The coaptation surface length calculated in two orthogonal views was 3.9 mm. After insertion of IABP, the average annular diameter decreased to 35 mm and the average coaptation surface length increased to 5.5 mm (*Figure 1*; Supplementary material online, *Videos S1* and *S2*).

28 March 2018: TTE mildly dilated LV with preserved systolic function, moderately thickened MV leaflets, immobile posterior leaflet with diastolic doming of anterior leaflet suggesting rheumatic aetiology, severe regurgitation, severe tricuspid regurgitation, and severely elevated pulmonary systolic pressure (65 mmHg)
29 March 2018: TOE no left atrial appendage (LAA) thrombus and severe MR with small coaptation surface
1 April 2018: IABP insertion to allow better leaflet coaptation
3 April 2018: MC procedure under TOE guidance showing adequate leaflet coaptation
7 April 2018: Discharged home under oral medical therapy for CHF
22 April 2018: Patient in NYHA Class I and has not had any admission for heart failure. Mild-moderate MR on TTE

Patient 3

17 September 2016: Posterior wall STEMI, undergoes PCI to LCX
18 September 2016: TTE moderate-severely dilated left ventricle with moderate-severely reduced global systolic function (ejection fraction 31%), moderate-severely dilated LA, moderately reduced right ventricle systolic function, mildly thickened MV leaflets with apical tethering causing incomplete closure and severe MR, and moderately elevated pulmonary systolic pressure
26 September 2016: Improvement of CHF symptoms under medical therapy, discharged home
30 September 2016: Readmitted for worsening CHF signs/symptoms and NSTEMI
10 October 2016: Undergoes PCI to right coronary artery with no improvement of CHF
31 October 2016: TOE severe/'free' MR, non-coaptating leaflets, and IABP is inserted
2 November 2016: Undergoes MC procedure after repeat TOE showing adequate coaptation surface
9 November 2016: Significant CHF signs/symptoms improvement, discharged home
10 March 2017: Patient in NYHA Class II has had only one hospitalization for worsening CHF. TTE showed mild-moderate MR

Patient 4

24 December 2017: Admission for worsening CHF and pneumonia needing mechanical ventilation
24 December 2017: TTE normal size left ventricle with normal global systolic function, severely dilated LA, normal size right ventricle with normal systolic function, mitral annular calcification, mildly thickened MV leaflets, restricted motion of the posterior leaflet causing severe regurgitation, moderate-severe TR, and moderate-severely elevated pulmonary systolic pressure
20 January 2017: Slight improvement in CHF signs/symptoms, failure to wean from ventilator, and undergoes tracheotomy
28 January 2017: Develops ventilator associated pneumonia and septic shock
28 February 2017: TTE mildly dilated LV with mild-moderately reduced systolic function, severe MR, and severe pulmonary hypertension
2 March 2017: Undergoes IABP insertion
4 March 2017: Undergoes successful MC procedure after repeat TOE showing better leaflet coaptation surface
9 March 2017: Develops multiorgan failure and dies

She underwent the procedure with no major complications. Two clips were implanted with a decrease of MR grade from +4 to +2 and no evidence of mitral stenosis.

Follow-up and outcomes

The IABP was removed 12 h following the procedure after assuring stable clinical and euvolemic status. The patient was discharged few days later in good condition, with no additional episodes of pulmonary oedema. Three months after discharge, the patient was stable at New York Heart Association (NYHA) functional Class II. Transthoracic echocardiography showed only mild MR with borderline LV systolic function (EF 50%).

Patient 2

Patient information

An 80-year-old female patient with a prior history of hypertension, chronic hepatitis C carrier, paroxysmal atrial fibrillation, cerebrovascular accident, and rheumatic heart disease with known severe MR. She was admitted to the cardiac intensive care unit due to pulmonary congestion.

Physical examination

On examination, she was in respiratory distress, her respiratory rate was 30 breaths/min, and her oxygen saturation was 86%. She had a clearly audible pansystolic murmur, and her lung examination was suggestive for pulmonary oedema.

Interventions

Transoesophageal echocardiography showed severe MR with practically non-coapting leaflets. An IABP was inserted 24 h prior to the procedure when the patient was euvolemic after diuretic therapy, with the aim of altering LV geometry to optimize the chances of success of MC by improving leaflet coaptation surface length and annular diameter. Baseline average annular diameter on TOE was 48 mm and the average coaptation surface length was 1.8 mm. After insertion of IABP, the average annular diameter decreased to 39 mm and the average coaptation surface length increased to 5.2 mm. Three mitral clips were implanted reducing MR severity from severe to mild-moderate and atrial V-wave from 60 to 25 mmHg (*Figure 2*; Supplementary material online, *Videos S5–S7*).

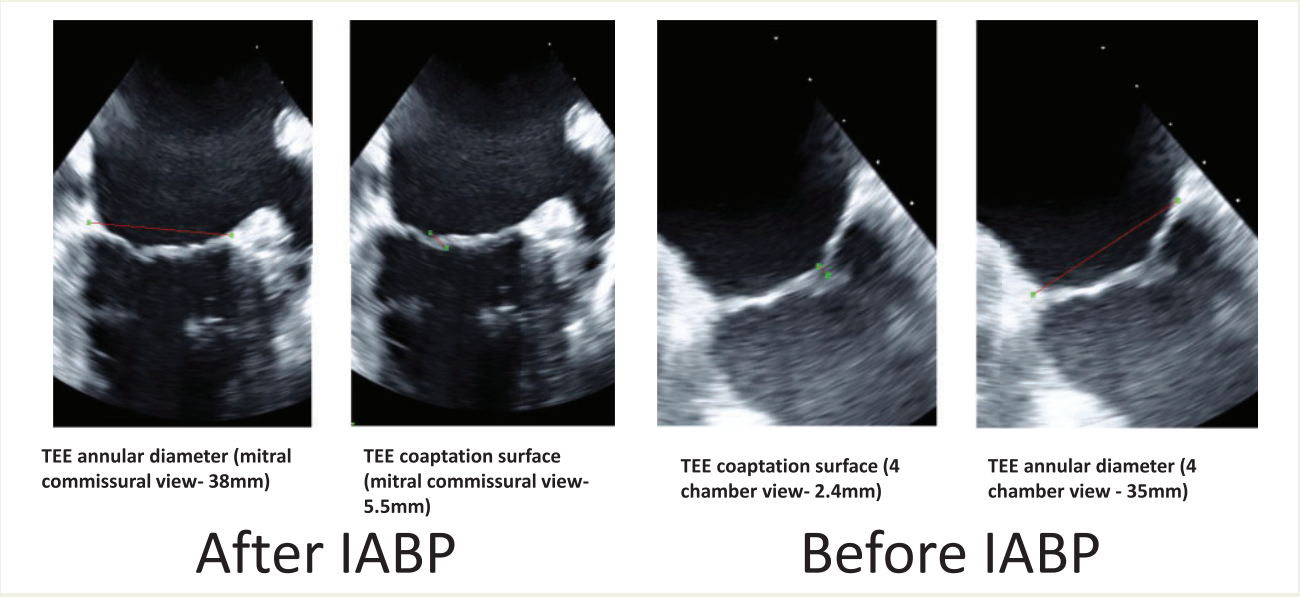

Figure 1 Average annular diameter and coaptation surface length before and after insertion of intra-aortic balloon pump in Patient 1.

Follow-up and outcomes

The IABP was removed 24 h following the MC procedure after assuring stable haemodynamic and euvolemic status. The patient was discharged a few days later in good condition, with no additional episodes of pulmonary oedema. Three months after discharge, the patient was stable at NYHA functional Class I. Follow-up TTE showed mild-moderate MR and mild-moderate LV systolic function (EF 45%).

Patient 3

Patient information

A 74-year-old female patient with a prior history of hypertension, hyperlipidaemia, diabetes, asthma, chronic renal failure, and ischaemic heart disease. Two months prior to her admission, she was treated in the cardiac intensive care unit for inferior-lateral ST-elevation myocardial infarction and underwent percutaneous coronary intervention (PCI) to the left circumflex (LCX) artery.

Physical examination

On examination, she was in respiratory distress (25 breaths/min) and her oxygen saturation was 86% on room air. Upon auscultation, she had a clear audible systolic murmur radiating to her left axilla, had diminished lung sounds in the bases and crackles suggestive for pulmonary oedema.

Interventions

The patient did not improve despite maximal medical therapy and remained in NYHA Classes III–IV. Transoesophageal echocardiography showed severe MR with practically no leaflet coaptation ('Free MR'), and other causes for severe MR (VSD/papillary muscle rupture, etc.) were excluded. Prior to the procedure an IABP was placed for 48 h to help maintain clinical stability and euvolemic status, and to achieve LV geometry alteration thus allowing better leaflet coaptation to optimize MC success. Mitral valve measurements using TOE showed an average annular diameter of 42 mm, and coaptation surface length of 1.9 mm. After insertion of IABP, the average annular diameter was 34 mm and the average coaptation surface length was 4.4 mm (*Figure 3*); see Supplementary material online, *Videos S3* and *S4*). The patient underwent implantation of three MCs, with a good overall results and improvement of the MR from severe to mild-moderate.

Follow-up and outcomes

Following the MC procedure for 48 h, the patient was weaned from the IABP after assuring stable haemodynamic status. The patient was discharged a few days later in good condition, with major improvement in NYHA symptoms and no additional episodes of pulmonary oedema. Three months after discharge, the patient was stable at NYHA Class II. Follow-up TTE showed moderate MR with moderately reduced LV function (EF 40%).

Patient 4

Patient information

An 80-year-old female patient with a prior history of hypertension, hyperlipidaemia, diabetes, and ischaemic heart disease with a prior inferior MI and PCI with drug-eluting stent placement to LCX, 3 years prior to her current admission. She was admitted with respiratory failure due to pulmonary oedema and pneumonia.

Physical examination

The patient was conscious, intubated, and ventilated with remarkable tachypnoea, her blood pressure was 80/50 mmHg and her pulse 100 b.p.m. There were decreased lung sound in both bases, heart sounds were irregular and fast, periphery was cold and dry.

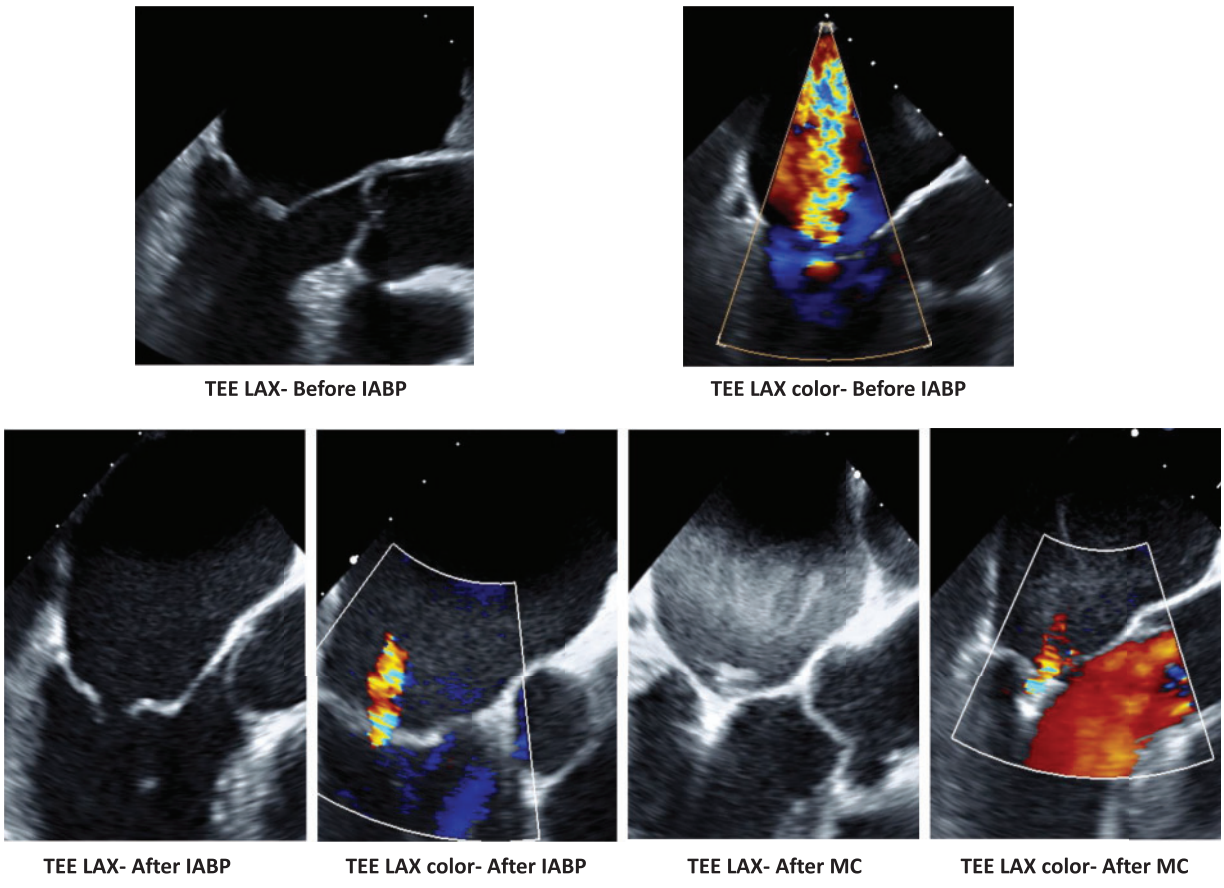

Figure 2 (A, *B*) Transoesophageal echocardiography long-axis view with and without colour Doppler before intra-aortic balloon pump, with and without colour Doppler after intra-aortic balloon pump and after MitraClip.

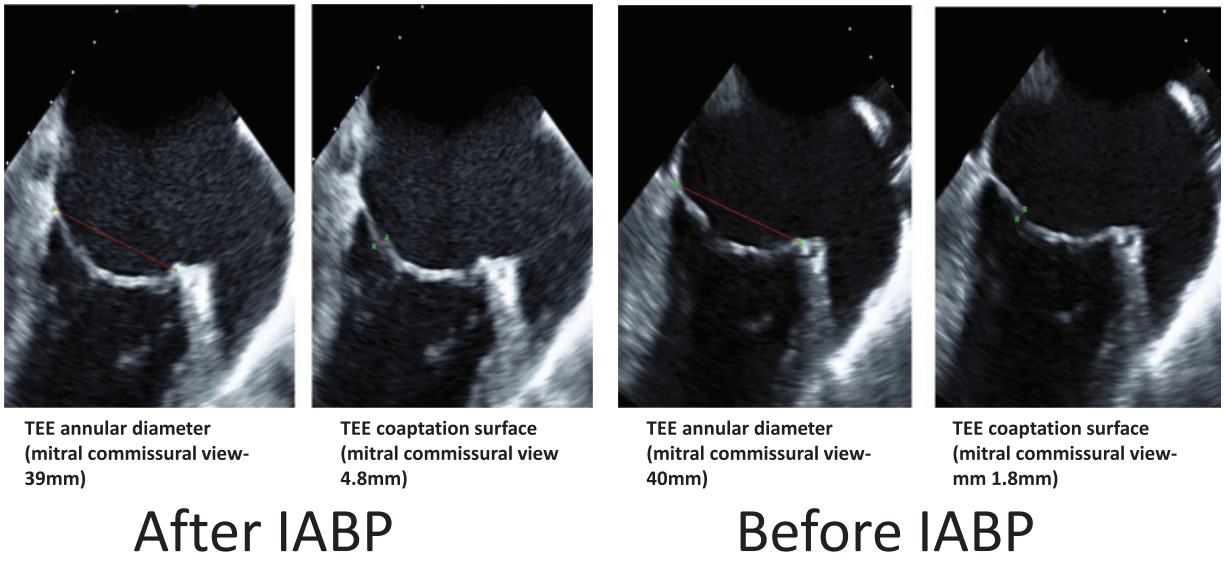

Figure 3 Average annular diameter and coaptation surface length before and after insertion of intra-aortic balloon pump in Patient 2.

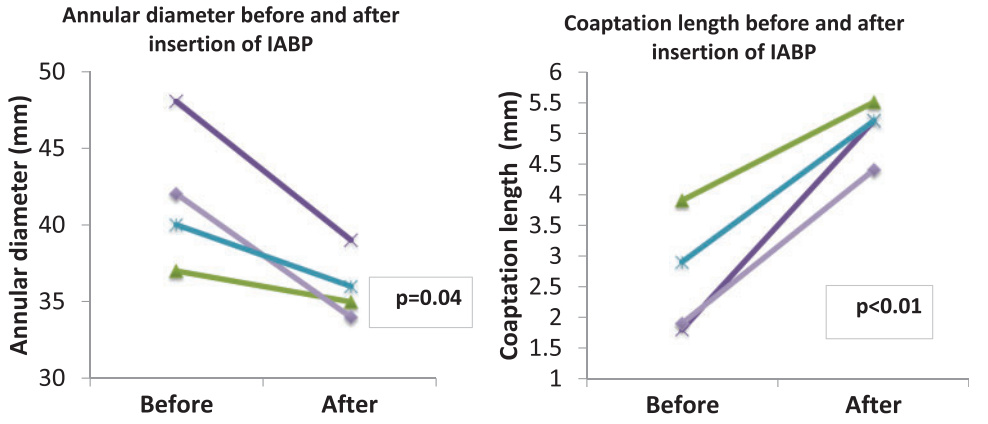

Figure 4 Average mitral annuls diameter and coaptation surface in study patients. All measurements were obtained prior and after the insertion of intra-aortic balloon pump and the values were compared using the paired Student's *t*-test.

Interventions

Initial TTE upon admission showed normal size LV with normal global systolic function, severe ischaemic MR (posteriorly directed wall jet), and no stenosis. After a 10-day period with improvement of infectious status, but no improvement in her CHF signs and inability to wean from mechanical ventilation due to continuous pulmonary congestion, a decision was made to perform urgent mitral clipping as salvage therapy. Prior to the procedure, TOE was performed that showed severe MR with a posteriorly directed jet, severe malcoaptation mainly resulting from posterior leaflet immobility, and no evidence of papillary muscle rupture or new VSD. Mitral valve measurements were based on TOE prior to the procedure: average annular diameter was 40 mm and average coaptation surface length was 2.9 mm. An IABP was inserted 3 days prior to the procedure as means of haemodynamic support and aim of altering LV geometry to optimize the chances of success of MC by improving leaflet coaptation surface length and annular diameter. Transoesophageal echocardiography after insertion of IABP showed an average annular diameter of 36 mm and average coaptation surface length was 5.2 mm. Two MCs were implanted (one medially and one laterally to the prominent calcification). Mitral regurgitation improved from severe to moderate and atrial V-wave decreased from 60 to 25 mmHg, with no immediate post-procedural complications.

Follow-up and outcomes

Following the procedure there was an initial improvement in in her respiratory condition, the IABP was kept *in situ* to allow better haemodynamic and vulemic support. Unfortunately 7 days after the procedure, she developed ventilator associated pneumonia and sepsis with multiorgan failure, she died 10 days following the procedure.

Discussion

The specific anatomy best suited for MC therapy includes a relatively central MR jet origin and a coaptation gap of <15 mm. Mitral regurgitation that arises from the commissures is particularly difficult to treat with MC. Similarly, large flail segments with an excess of coaptation gap have a high failure rate with MC therapy.[7]

In our experience, treating this unique and complex subpopulation of patients suffering from severe symptomatic MR, based on current accepted criteria, both echocardiographic and anatomical, were not suitable candidates for MC procedure. Using the aid of IABP system enabled us to overcome mitral leaflet gap and complete the procedure of MC uneventfully. In all cases, IABP insertion resulted in a 2–9 mm decrease in mean annular diameter and an increase of 1.6–3.4 mm average in coaptation surface allowing performance of the MC (*Figure 4*). The beneficial effects of IABP were noted immediately after its insertion, reducing afterload, and change in LV geometry and valvular apparatus. This in turn led to better leaflet coaptation via reduction in annular diameter, increase in coaptation surface, and allowing better mitral leaflet grasping and durable result in terms of MR reduction and avoidance of mitral valve stenosis. This feature of the IABP and its effect on LV highlights its important role in the immediate procedural phase and overall procedural success in this unique and very complicated patient population.

This indicates that the effects of the IABP on procedural success could be explained both by the pure haemodynamic effect on LV via unloading and afterload reduction, and also via a direct action on mitral valve anatomy and physiology, by allowing leaflet coaptation irrespective to LV function. Importantly, had there been no improvement in the patient haemodynamic and mitral valve parameters the decision to go forth with the MC procedure would have been on a case by case basis. In a few other cases, we have tried to perform MC procedure using IABP albeit failing to improve LV and mitral valve leaflet dimensions unfortunately with poor results. This fact outlines the importance of patient selection combined with the use of IABP to allow a successful MC procedure.

Technical procedural decisions as to the number of clips implanted (between 2 and 3) in each patient was dependent on the coaptation surface defect and the amount of MR. As a result, some patients needed two clips to achieve significant MR reduction without causing MS and in others three clips were needed to achieve a durable result

without causing significant MS. This is in line with current practice methods in the treatment of severe MR.

Thus, we recommend expanding the indications and use of IABP to both patient populations, allowing then to benefit from percutaneous mitral valve repair via MC.

Conclusion

We presented four patients with heart failure and severe MR and non-coaptating valve leaflets. In each case we succeeded in achieving better leaflet coaptation by inserting IABP allowing an MC procedure in an otherwise unsuitable/precluded case.

Lead author biography

Dr Ran Eliaz began his medical training at the Semmelweis University from which he graduated with honour at 2008. He then continued his practical training in the field of Internal medicine and Cardiology at the Hadassah university hospital in Jerusalem between the years 2009 and 2018. He is currently working as an academic and interventional cardiology fellow at the Heart Institute Hadassah Medical Center.

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 author/s confirm that written consent for submission and publication of this case report including image(s) and associated text has been obtained from the patient in line with COPE guidance.

Conflict of interest: none declared.

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