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CASE REPORT
Valvular heart disease

Mitral valve repair with papillary muscle repositioning for functional mitral regurgitation (Type IIIb) with metal allergies: a case report

Atsuyuki Mitsuishi [1]*, Yujiro Miura[1], and Toru Kubo [2]

[1]Department of Cardiovascular Surgery, Kochi Medical School Hospital, 185-1, Kohasu, Okohcho, Nankoku-shi, Kochi Prefecture 783-8505, Japan; and [2]Department of Cardiology and Geriatrics, Kochi Medical School Hospital, 185-1, Kohasu, Okohcho, Nankoku-shi, Kochi Prefecture 783-8505, Japan

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Background Prosthetic heart valves, rings, and clips commonly used in heart surgery may contain metals, such as nickel and cobalt, that can cause severe hypersensitivity reactions in allergic patients. These reactions can cause paravalvular leakage and valve dysfunction. Similarly, stainless steel sternal wires can cause contact dermatitis. We should select rings, valves, and wires that do not contain any metals known to cause allergies in patients undergoing cardiac surgery.

Case summary We report the case of a 79-year-old man with severe functional mitral regurgitation (Type IIIb) and a history of nickel and cobalt allergies. We safely performed mitral valve repair with papillary muscle repositioning with nickel- and cobalt-free rings in this patient. He was discharged from the hospital on the 26th postoperative day without dialysis intervention. Two years after surgery, mitral and tricuspid regurgitation had not worsened.

Discussion According to the 2020 American Heart Association guidelines, surgery for severe functional mitral valve insufficiency (Type IIIb) is considered class IIb. Meanwhile, transcatheter edge-to-edge repair is class IIa. Long-term regurgitation is difficult to control with valve replacement and annuloplasty alone; recurrence has been observed. Therefore, additional techniques were considered. Papillary muscle repositioning has been reported and shown good results. The method used in the present case made intervening in the subvalvular tissue easy and demonstrated technical feasibility, safety, and effectiveness.

Keywords Functional mitral regurgitation • Metal allergies • Papillary muscle repositioning • Spiral suspension • Mitral valve repair • Case report

ESC Curriculum 2.2 Echocardiography • 4.3 Mitral regurgitation • 7.5 Cardiac surgery • 6.5 Cardiomyopathy • 4.5 Tricuspid regurgitation

Learning points

- Patients with metal allergies and requiring valvular repair/replacement surgery pose a unique clinical challenge.
- We safely performed mitral valve repair with papillary muscle repositioning with nickel- and cobalt-free rings to treat a patient with functional mitral regurgitation (Type IIIb) and nickel and cobalt allergies.

* Corresponding author. Tel +81-88-880-2375 (Office), +81-88-866-5811 (Hospital), Email: atmitsu@kochi-u.ac.jp
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Introduction

Prosthetic heart valves, rings, and clips commonly used in heart surgery may contain metals, like nickel and cobalt, that cause severe hypersensitivity reactions in allergic patients. These reactions can result in paravalvular leakage, leading to valve dysfunction.[1] Similarly, contact dermatitis, including pruritus or pain in the sternum, can develop in reaction to monofilament stainless steel sternum wire. Therefore, in patients with known metal allergies, the use of artificial valves, clips, and sutures containing any metal allergens should be avoided.

According to the 2020 American Heart Association (AHA) guidelines,[2] surgery for severe functional mitral valve insufficiency (Type IIIb) is considered class IIb; transcatheter edge-to-edge repair (TEER) is class IIa. Long-term regurgitation is difficult to control with valve replacement and annuloplasty alone,[3,4] and recurrence has been observed. Therefore, additional techniques were considered. Papillary muscle repositioning has been reported and shown good results. Herein, we safely performed mitral valve repair with papillary muscle repositioning using nickel- and cobalt-free rings to treat a patient with functional mitral regurgitation (Type IIIb) and nickel and cobalt allergies.

Summary Figure

Twelve years before admission to our hospital

Echocardiography: left ventricular end-diastolic (LVEDD) and end-systolic diameters (LVESD) were 63 and 45 mm, respectively. Ejection fraction (EF) of 49%, mild mitral regurgitation (MR), and cardiac dysfunction were observed. Medical treatment was initiated.

Six years before admission to our hospital

Echocardiography: LVEDD and LVESD had improved to 57 and 45 mm, respectively. EF was approximately 60%; however, taking oral medication became difficult due to traumatic subdural haematoma, and MR gradually worsened.

One year before admission to our hospital

MR became severe, and the patient was hospitalized with symptoms of heart failure. Heart failure improved with medical treatment.

Five months before admission to our hospital

Dyspnoea on exertion and pulmonary hypertension developed, which were improved with medical treatment.

One month before admission to our hospital

Dyspnoea on exertion worsened, and the patient was readmitted to the hospital. Due to recurrent heart failure, an elective surgery was planned after the previous hospital admission, following the successful management of heart failure.

Postoperative day (POD) 0: The patient was extubated.

POD 13: LVEDD and LVESD had improved to 62 and 53 mm, respectively. EF was approximately 40%, and MR was trivial.

POD 25: The patient was discharged from the hospital.

Case presentation

The patient was a 79-year-old man with a history of methicillin-resistant *Staphylococcus aureus* infection (acquired during brain surgery), mitral regurgitation (MR), chronic atrial fibrillation for 9 years, and decreased left ventricular contractility.

He had eight long-term hospitalizations during which he underwent multiple operations. Metal allergies to nickel (Ni) and cobalt (Co) were detected 8 years prior. The MR gradually worsened and became more severe. Dyspnoea on exertion appeared approximately 2 years prior and gradually worsened.

One year prior, he was hospitalized for heart failure. Soon after discharge, he gained weight and experienced dyspnoea on exertion, accompanied by lower-leg oedema. Echocardiography showed severe MR, reduced ejection fraction (EF, 50%), and deterioration of pulmonary hypertension (pulmonary pressure: 37/16/25 mmHg).

Because of recurrent heart failure, an elective surgery was planned after the previous hospital admission, following the successful management of heart failure. Preoperative echocardiography showed the following: left ventricular internal end-diastolic (LVEDD) and end-systolic diameters (LVESD) of 68 and 48 mm, respectively—EF of 45%, severe MR with central jet (tenting height, 12 mm) (*Figures 1* and *2A*), moderate tricuspid regurgitation (TR) (tenting height, 8 mm) (*Figure 2B*), a left atrial diameter of 66 mm, and progressive MR with increased diuretics. Using coronary angiogram and technetium-99m, cardiologists ruled out ischaemia and amyloidosis as the cause of LV dysfunction. Although the LV size was large, the LVEF was over 40% and the wall thickness was approximately 13 mm. Therefore, it was not a typical dilated cardiomyopathy (DCM); yet DCM could not be excluded as the cause of LV dysfunction.

Prosthetic valves, rings, and TEER containing Ni and Co were contraindicated. Additionally, the sternal closure required a Ni- and Co-free sternal wire. We selected Ni- and Co-free rings for mitral and tricuspid annuloplasty. We used titanium wire for sternal closure as stainless steel can contain traces of nickel. Cardiopulmonary bypass was established through median sternotomy using standard aortic and bicaval cannulation. Antegrade blood cardioplegia was administered, and the left atrium was accessed via a transseptal approach.

No chord rupture was observed. Left atrial ablation was performed using a modified maze procedure with cryoablation. The left atrial appendage was then resected. A 28-mm Ni- and Co-free Séguin Ring (Séguin Semi-Rigid Annuloplasty Ring; Abbot Medical, Austin, TX, USA) was chosen for mitral valve repair. After the annular mattress sutures were tied, they were passed around the annuloplasty ring again, taking additional bites of atrial tissue and tied again (the double-suture technique). The tricuspid valve was examined after the closure of the

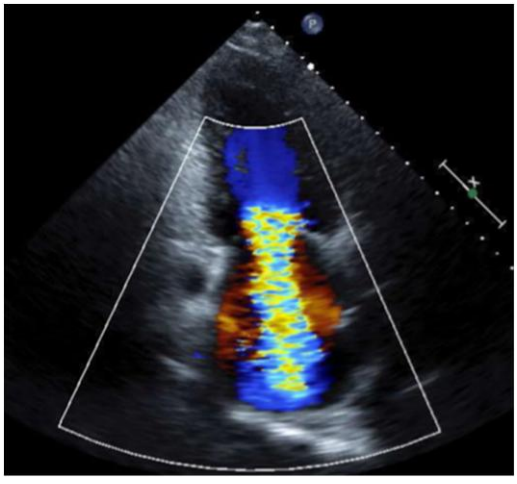


Figure 1 Mitral regurgitation with central jet.

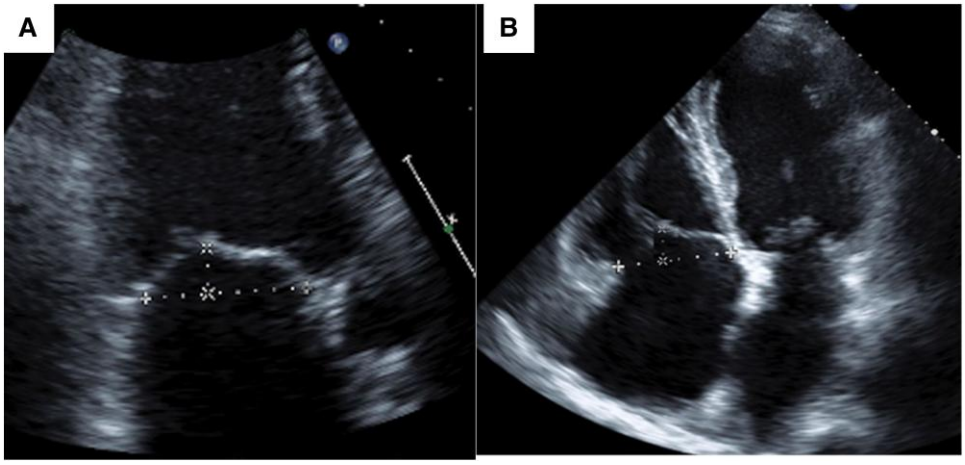


Figure 2 (*A*) Mitral valve; tenting height 11.1 mm and annulus 39 mm. (*B*)Tricuspid valve; tenting height 9.3 mm, tenting area 2.83 mm^2, and annulus 49 mm.

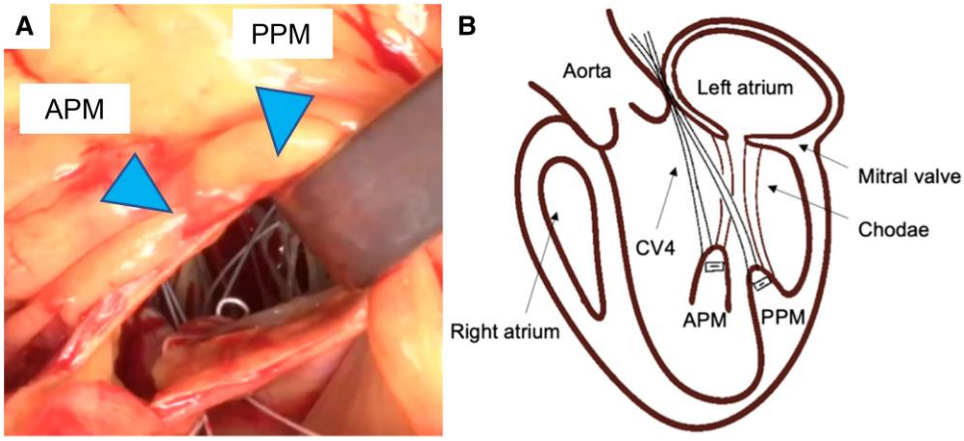


Figure 3 (*A*, *B*) Papillary muscle repositioning; a pair of CV-4 sutures was passed through the anterior and posterior papillary muscles (APM and PPM, respectively), and papillary muscle refixation and ligation were added through the aorto-mitral continuity and aortic valve.

interatrial septum. The diameter of the annulus was 55 mm. In addition to annulus enlargement, tethering was also contributing to regurgitation.

Subsequently, a pledgeted CV4 suture (GORE-TEX® Suture; W. L. Gore & Associates Inc., Newark, DE, USA) was placed at the base of the anterior papillary muscle (PM) and continuously sutured clockwise to the base of the secondary and then inferior PM. The CV4 suture crossed the interventricular septum and externalized the septal ring of the right atrium. After tricuspid annuloplasty using a 27-mm Ni- and Co-free ring (Duran Flexible Partial Ring; Medtronic Inc., Minneapolis, MN, USA) the CV4 suture was passed through the ring. Suture length adjustments were performed under a water test, and the sutures were tied (spiral suspension technique).

Next, a pledgeted CV4 suture was passed through the head of the anterior and posterior PM via an aortotomy. It was passed from the left ventricular cavity through the mid-septal fibrous annulus and exteriorized through the aortic wall beneath the commissure between the non-coronary and left coronary aortic cusps (PM repositioning) (*Figures 3A* and *B*). Aortotomy was closed with two layers of continuous sutures, and the sternum was closed with a pure titanium wire (Yokozuna wire; USCI Holdings, Tokyo, Japan). Transoesophageal echocardiography confirmed that the MR and TR had disappeared. Postoperative transthoracic echography revealed a trivial MR (tenting height, 8 mm) and disappearance of TR.

After undergoing treatment for heart failure in the cardiology department, the patient was discharged from the hospital on the 26th postoperative day without dialysis intervention. Two years after surgery, MR and TR had not worsened on echocardiography (*Figure 4A, B*).

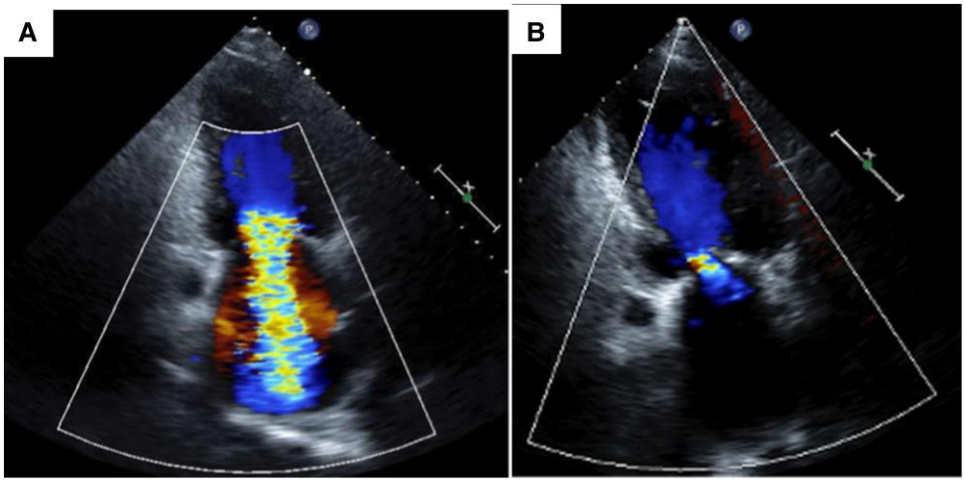


Figure 4 Mitral valve echocardiography (*A*) preoperative image. (*B*) Postoperative image.

Table 1 Metal components of surgical materials in Japan

Mitral bioprosthetic valve	MITRIS RESILIA	Ni, Co, Cr, Mo, Mn, C, Be, Fe
	EPIC	Ni, Co, Mo, Mn
	Mosaic	alloy (Co, Cr, W, Ni, Fe, Mn, Si, C)
Mitral mechanical valve	SJM Regent/Masters	Ni/Co alloy, Cr, Mo, W
	SJM Standard	No metal
	ATS AP 360	C, Ti alloy (N, C, Fe, Al, Ba, Ti), Ni/Co/Cr alloy
	ATS Standard	Ti alloy (N, C, Fe, Al, Ba, Ti)
	ON-X	Ti alloy (Ti, Al, V, N, C, H, Fe, O)
Ring or band for mitral valve	Profile 3D Ring	Ti alloy
	CGFuture Ring & Band	Ni, Co, Cr, Mo alloy
	Duran ring	No metal
	Simu Form	Ni/Co/Cr/Mo alloy
	Simu Plus ring	W
	PhysioII (5200)	Ni, Co, Cr
	PhysioFlex (5300)	Ni/Ti alloy
	Rigid Saddle Ring	Metal Free
	Seguin	Metal Free
Ring or band for tricuspid valve	Contour-3D	Ti alloy
	Tri-ad2.0 ring	Ni/Co/Cr/Mo alloy
	MC^3(4900)	Ti alloy, Al, Ba
	PhysioTricuspid (6300)	Ti alloy, Al, Ba
	MEMO 3D/MEMO 4D	Ni, Co, Cr, Cu. C, Fe, Ti, Nb
Ring or band for mitral & tricuspid valve	Cosgrove (4600)	Metal free
	Tailor Ring & Band	Metal free
	Duran Ring & Band	Metal free
Clip	MitraClip	Co/Cr alloy, Ni/Ti alloy
Wire	Cosmo wire	Ni, Cr, Mo, Fe alloy
	Yokozuna	Ti

Ni, nickel; Co, cobalt; Cr, chromium; Mo, molybdenum; Mn, manganese; Be, beryllium; Fe, iron; W, tungsten; Ti, titanium; Ni, nickel; Si, silicon; C, carbon; Al, aluminium; Ba, barium; V, vanadium; N, nitrogen; H, hydrogen; O, oxygen; Cu, copper; Nb, niobium.

Discussion

Prosthetic heart valves, rings, and clips commonly used in heart surgery may contain metals that can cause severe hypersensitivity reactions in allergic patients. These reactions can cause paravalvular leakage, leading to valve dysfunction.[1]

Herein, we report the case of a patient with functional MR (Carpentier Type IIIb) and metal allergies. Guidelines recommend TEER (American College of Cardiology (ACC)/AHA Guideline class IIa) and mitral valve surgery (ACC/AHA Guideline class IIb) for patients with functional MR.[2] However, TEER (MitraClip™; Abbot Medical) could not be used due to the patient's allergy. Patients with severe nickel allergies have been reported to be discharged from the hospital without serious complications following aortic valve replacement with On-X Aortic Valve (CryoLife, Kennesaw, GA, USA).[5] Valve replacement can produce a short pump run and has a low risk of a re-run. However, because of the patient's history of subdural haematoma, we avoided using a mechanical valve which would involve taking warfarin. Also, all biological valves (*Table 1*) available in Japan contain Ni, Co, or alloys, excluding them from consideration for this patient.

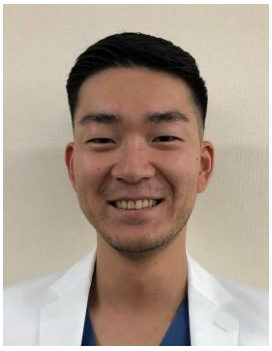
As the metal components of alloys are often unclear, we selected rings without alloys, Ni, or Co and those we had used before. However, it is difficult to control regurgitation during the long-term period and recurrence has been reported.[3,4] Therefore, techniques other than annuloplasty are being considered in cases where valves cannot be used. PM repositioning has shown good results,[6,7] although neo-chord implantation in combination with a stabilizing annular ring can be quicker and less extensive. Thus, PM repositioning was added in this case to prevent long-term regurgitation recurrence.

Posterior PM repositioning alone may be sufficient for ischaemic functional MR.[8] However, in this case, due to LV systolic dysfunction of unknown aetiology, the possibility of DCM was considered and both anterior and posterior PM repositioning were performed in accordance with Langer *et al*.[9] Additionally, in TR with severely tethered leaflets, repair with ring annuloplasty alone cannot prevent residual or recurrent TR. Rigid ring annuloplasty showed a lesser incidence of late TR recurrence than other valve repairs, including ring-spare techniques such as De Vega.[10] Eishi *et al*.[11] reported a spiral suspension technique that approximates the anterior PM, accessory PM for the inferior leaflet (inferior accessory PM), and inferior PM. We used this technique and rigid ring annuloplasty to treat TR with severely tethered leaflets.

Additionally, attention was paid to the sternal closure in this patient, which required a Ni- and Co-free sternal wire. A few cases with metal allergies where alternative sutures were used instead of monofilament stainless steel in cardiac surgery have been reported.[12,13] However, these alternative materials have problems with strength. Considering the price in Japan, we used a wire made of pure titanium instead of a sternal plate. Titanium wire (Yokozuna wire; USCI Holdings) has a tensile strength of ≥160% (strength after fastening the thoracic bone model) compared to the stainless wire that was selected.

In conclusion, we performed mitral valve repair, with additional subvalvular surgical techniques for long-term regurgitation control, to treat functional MR in a patient with Ni and Co allergies. Follow-up with medium- to long-term evaluations, assessing for MR exacerbation and left ventricular re-expansion, is important. The methods used in this case made intervening in the subvalvular tissue easy and demonstrated technical feasibility, safety, and effectiveness.

Lead author biography



I've graduated from Niigata university, Niigata, Japan. I'm working at Kochi Medical School Hospital, Kochi, Japan. My main area of interest includes cardiovascular surgery.

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Data availability

No new data were generated or analysed in support of this research.

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