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CASE REPORT
Cardiac imaging

Combined ablation for paroxysmal atrial fibrillation and drug-refractory hypertrophic obstructive cardiomyopathy: a case report

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Background Hypertrophic obstructive cardiomyopathy (HOCM) is sometimes concomitant with atrial fibrillation (AF) and exacerbates heart failure symptoms. Although optimal medication for the reduction of left ventricular outflow tract (LVOT) obstruction and the maintenance of sinus rhythm should be considered, it is difficult to control the symptoms permanently.

Case summary A 45-year-old man, diagnosed with HOCM, presented with progressive dyspnoea on exertion, which significantly deteriorated during episodes of paroxysmal AF, despite optimal medical therapy. On echocardiography, we found LVOT obstruction with a peak pressure gradient of 98 mmHg, concomitant with redundant mitral valve leaflets, which caused significant systolic anterior motion (SAM). Since he declined open surgery, we selected a combination of catheter interventions, AF ablation, and alcohol septal ablation (ASA). After the AF ablation, the occurrence of AF significantly decreased, and there was no recurrence after the ASA. By 6 months, the plasma N-terminal pro-B-type natriuretic peptide level had decreased from 1022 to 124 pg/mL, the peak pressure gradient of LVOT decreased from 98 to 12 mmHg, and the left atrium volume decreased from 203 to 178.4 mL. The improvement in the SAM was visualized on echocardiography and was haemodynamically corroborated by the four-dimensional (4D)-flow cardiac magnetic resonance (CMR).

Discussion The treatment of drug-refractory HOCM concomitant with paroxysmal AF needs both septal reduction and the maintenance of sinus rhythm, which can be accomplished through transcatheter interventions. Moreover, the detailed intra-ventricular haemodynamic assessment in HOCM patients can be explored using the 4D-flow CMR.

Keywords Case report • Hypertrophic obstructive cardiomyopathy • Atrial fibrillation • Alcohol septal ablation • 4D-flow MRI

Learning points

- The treatment of drug-refractory hypertrophic obstructive cardiomyopathy (HOCM) concomitant with paroxysmal atrial fibrillation can be accomplished through transcatheter interventions.
- The detailed intra-ventricular haemodynamic assessment in HOCM patients can be explored using the 4D-flow cardiac magnetic resonance.

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Introduction

Hypertrophic obstructive cardiomyopathy (HOCM) causes a variety of symptoms, such as dyspnoea on exertion, chest pain, palpitations, and syncope, all of which reduce quality of life.[1,2] Hypertrophic obstructive cardiomyopathy is sometimes concomitant with atrial fibrillation (AF) because of the predisposition to AF in those with diastolic dysfunction and left atrial (LA) enlargement.[3] Atrial fibrillation in HOCM patients is generally poorly controlled with amiodarone.[4] We present a case of drug-refractory HOCM concomitant with AF, managed successfully using a combination of transcatheter therapies; pulmonary vein ablation, and alcohol septal ablation (ASA). Hypertrophic obstructive cardiomyopathy patients sometimes have elongated mitral valve leaflets, which reinforce the systolic anterior motion (SAM) of the mitral valve and left ventricular outflow tract (LVOT) obstruction. We successfully reduced the SAM after the ASA, despite the continued existence of elongated mitral valve leaflets. The images from four-dimensional (4D)-flow cardiac magnetic resonance (CMR) are presented to confirm the intra-ventricular haemodynamic changes before and after the ablations.

Timeline

Timeline	
2008	Diagnosed as hypertrophic obstructive cardiomyopathy, with New York Heart Association (NYHA) class II dyspnoea. Despite the initiation of taking atenolol, his dyspnoea did not improved.
2017	Atrial fibrillation (AF) was initially documented, and started taking Amiodarone and Rivaroxaban. His dyspnoea on exertion also gradually aggravated.
April 2018 (initial visit)	Consulted to our routine outpatient appointment, with NYHA class III dyspnoea. His AF burden was 7.1%, despite taking Amiodarone. During paroxysms of AF, his symptoms deteriorated to NYHA class IV.
	Since he also had the redundant mitral valve leaflets, the surgical myectomy with mitral repair and MAZE procedure was initially suggested. However, he declined open surgery.
	After a cardiac team conference, we decided to perform the AF ablation first, followed by the alcohol septal ablation (ASA).
July 2018	(Intervention) AF Ablation was performed.
	After the ablation, he remained symptomatic with NYHA class III, although sinus rhythm was maintained.
November 2018	(Intervention) ASA was performed.
December 2018	Dyspnoea improved to NYHA class I
May 2019	The follow-up echocardiography, computed tomography, and magnetic resonance imaging were performed.
May 2020	Atrial fibrillation had never relapsed, though Amiodarone was continued.

Case presentation

A 45-year-old man presented to our outpatient appointment with the complaint of dyspnoea on exertion. He was an office worker and his functional status was good. He had no past medical history other than the cardiac disease that is described hereafter. Ten years before the visit, he had experienced New York Heart Association (NYHA) class II heart failure symptoms and was diagnosed with HOCM on echocardiography. The LVOT peak pressure gradient at initial diagnosis was 35 mmHg. He was put on 12.5 mg of atenolol, which was further titrated to 25 mg soon after. His symptoms did not improve and gradually progressed to NYHA class III. Moreover, AF was initially documented 1 year before the consultation to our hospital and he had started taking amiodarone along with a direct oral anticoagulant.

While his symptoms were exacerbated by the AF, the AF burden was determined to be 7.1% with Holter electrocardiogram (ECG) monitoring whilst the patient was taking amiodarone. During paroxysms of AF, the patient reached NYHA class IV, however, the paroxysms terminated spontaneously and did not require electrical cardioversion. His blood pressure and heart rate at the initial appointment was 145/80 mmHg and 67 b.p.m., respectively, during sinus rhythm. The heart rate increased to 90 b.p.m. during AF. On physical examination, the systolic ejection murmur was auscultated in the lower-left sternum border, which enhanced during the Valsalva manoeuvre. There were no crepitations on auscultation of his lungs and no pitting oedema in his legs. His serum sodium and potassium levels were 144 and 4.8 mEq/L, respectively (reference level, 139–145, 3.6–4.8 mEq/L, respectively). His free T3, free T4, and thyroid-stimulating hormone level was 2.09 pg/mL, 1.11 ng/dL, and 1.62 μ international unit (IU), respectively (reference level, 1.88–3.18 pg/mL, 0.7–1.48 ng/dL, and 0.35–4.94 μIU, respectively). His plasma N-terminal pro-B-type natriuretic peptide (NT-proBNP) level was 1022 pg/mL (reference level, <125 pg/mL). The ECG during sinus rhythm showed a complete right bundle branch block, while there was no T-wave inversion in any leads (*Figure 1A*). The Holter ECG showed the paroxysmal AF with the burden of 7.1%, whereas neither long pause nor ventricular tachycardia was documented. The echocardiogram showed significant LVOT obstruction with a peak pressure gradient of 98 mmHg during the sinus rhythm (*Figure 1B–E* and *Movie 1*). There were elongated mitral valve leaflets, with 15 mm coaptation length, causing SAM and moderate mitral regurgitation (*Figure 2A* and *B*). The patient's left ventricular ejection fraction was preserved (79%). Therefore, his dyspnoea seemed to derive from

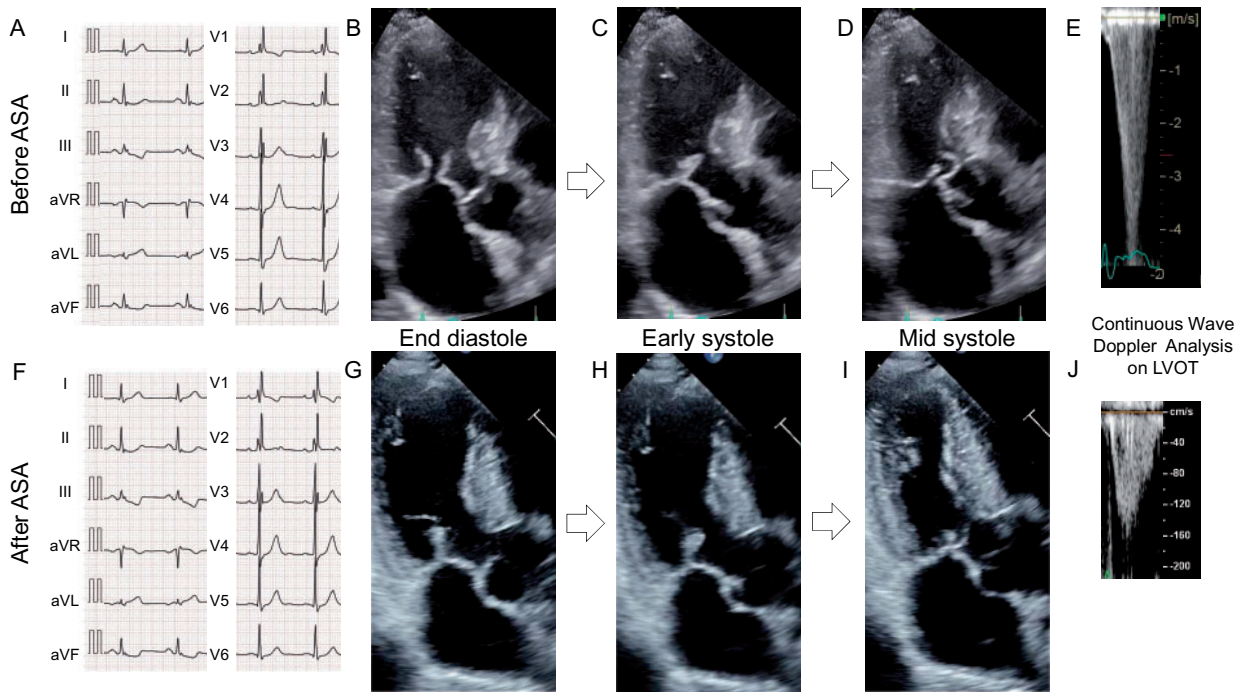
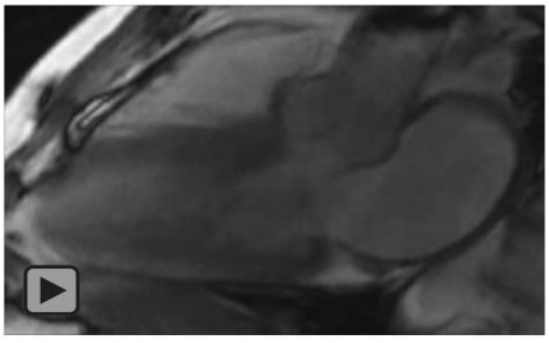


Figure 1 The electrocardiography and echocardiography on the first visit and 6 months after the alcohol septal ablation. (*A*) Electrocardiography before the alcohol septal ablation. (*B*) Early diastolic phase before the alcohol septal ablation. Both anterior and posterior mitral valve leaflets were elongated. (*C*) Early systolic phase before the alcohol septal ablation. Both mitral leaflets were approaching the basal septum. (*D*) Mid-systolic phase before the alcohol septal ablation. The anterior mitral leaflet contacted the basal septum. (*E*) The continuous wave Doppler assessment across left ventricular outflow tract before the alcohol septal ablation. The estimated peak pressure gradient in left ventricular outflow tract was 98 mmHg. (*F*) Electrocardiography after the alcohol septal ablation. The additional atrial-ventricular block did not occur. (*G*) Early diastolic phase after the alcohol septal ablation. The lengths of both mitral leaflets were constant. (*H* and *I*) Early- and mid-systolic phase after the alcohol septal ablation. Although the systolic anterior motion remained, the anterior leaflet did not contact the basal septum. (*J*) The continuous wave Doppler analysis across left ventricular outflow tract after the alcohol septal ablation. The estimated peak pressure gradient in left ventricular outflow tract was 12 mmHg.



Movie 1 Three-chamber cine images of cardiac magnetic resonance across the one cardiac cycle before the alcohol septal ablation.

LVOT obstruction and the subsequent decreased cardiac output, which was significantly exacerbated during AF.

Since he had drug-refractory HOCM with mitral structural abnormalities, surgical myectomy with mitral repair was initially suggested. However, he declined open surgery and requested catheter intervention. To ameliorate his heart failure symptoms, both septal reduction and the maintenance of sinus rhythm seemed necessary. After a cardiac team conference, we decided to perform the AF ablation first, followed by the ASA if needed. This was partly because we thought that the patient's symptoms were primarily related to AF and the reduction in cardiac output during AF, which would be alleviated by the AF ablation alone. Also, we took into consideration that the AF ablation might be delayed and complicated if a permanent pacemaker had to be implanted after the ASA.

Initially, pulmonary vein isolation was performed with a cryoballoon (Arctic Front Advance 28 mm, Medtronic, Minneapolis, MN, USA) and box-isolation was completed with a radiofrequency catheter (TACTICATH, Abbott, Abbott Park, IL, USA), inserting a 15-French sheath through the femoral vein. After AF ablation, the paroxysmal AF frequency decreased significantly, and the plasma NT-proBNP level decreased to 270 pg/mL (*Figure 3D*). Despite being relieved from the discomfort of the AF attack, the patient's symptoms remained at NYHA class III, with a peak pressure gradient of 77 mmHg through LVOT during sinus rhythm. After discussing in the heart team conference, we advanced with the ASA to relieve his

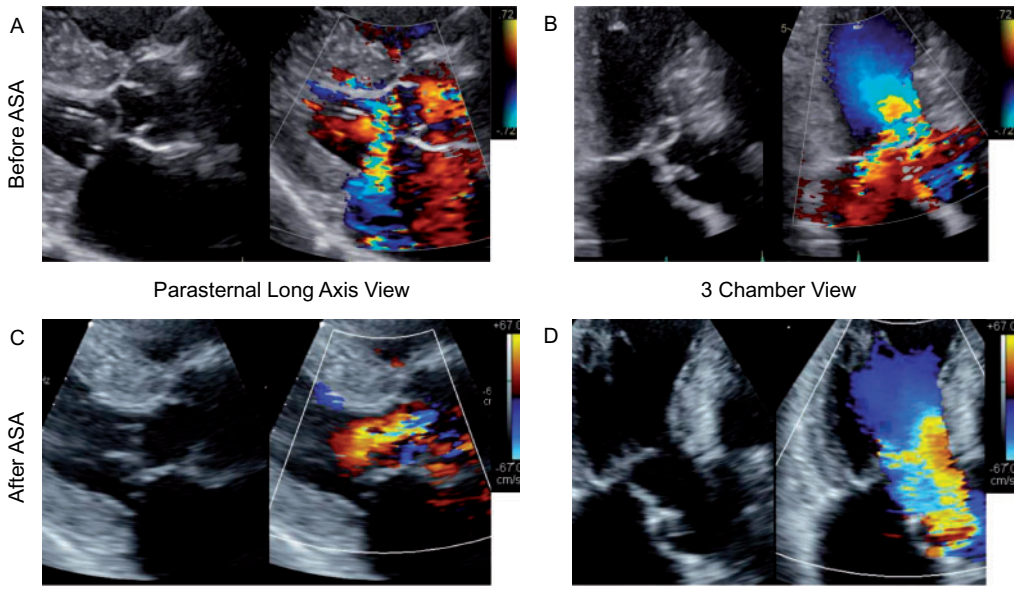


Figure 2 The comparison of B-mode and colour Doppler echocardiography in mid-systolic phase, before and 6 months after the alcohol septal ablation. (*A* and *B*) The parasternal long-axis view and three-chamber view of left ventricular outflow tract before the alcohol septal ablation, respectively. The systolic anterior motion-induced moderate mitral regurgitation occurred along the posterior side of left atrium. (*C* and *D*) The parasternal long-axis view and three-chamber view of left ventricular outflow tract after the alcohol septal ablation, although systolic anterior motion remained, the mitral regurgitation almost disappeared.

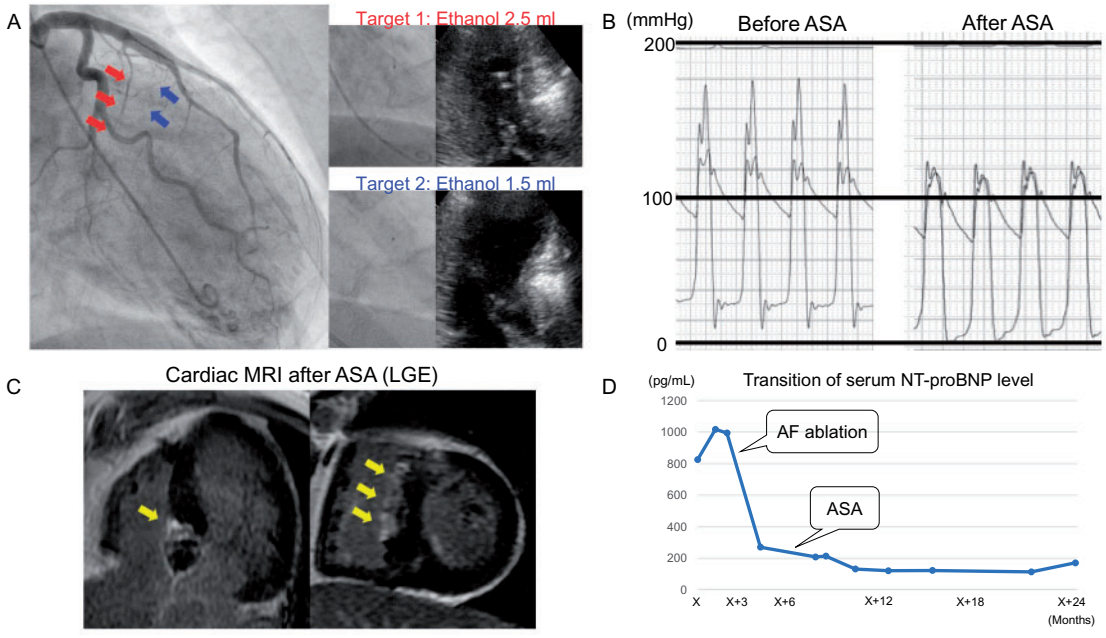


Figure 3 The coronary angiography, echocardiography, simultaneous pressure waveform, late gadolinium enhancement (LGE) on cardiac magnetic resonance, and serum N-terminal pro-B-type natriuretic peptide level around the alcohol septal ablation. (*A*) Initially, we set the first septal branch as target 1 (Red arrows). After confirming the stained area with contrast echocardiography, we ablated target 1 with 2.5 mL of ethanol. Second, we set the second septal branch as target 2 (Blue arrows) and ablated it with 1.5 mL of ethanol. (*B*) The simultaneous pressure gradient between left ventricle and ascending aorta changed from 55 to 7 mmHg during the alcohol septal ablation. (*C*) One week after the alcohol septal ablation, cardiac magnetic resonance confirmed the ablated basal septum (left: four-chamber view, right: short-axis view). (*D*) The serum N-terminal pro-B-type natriuretic peptide level significantly decreased after the atrial fibrillation ablation. The additional decrease of N-terminal pro-B-type natriuretic peptide was accomplished after the alcohol septal ablation. X means the day of his initial visit to our hospital. LGE, late gadolinium enhancement.

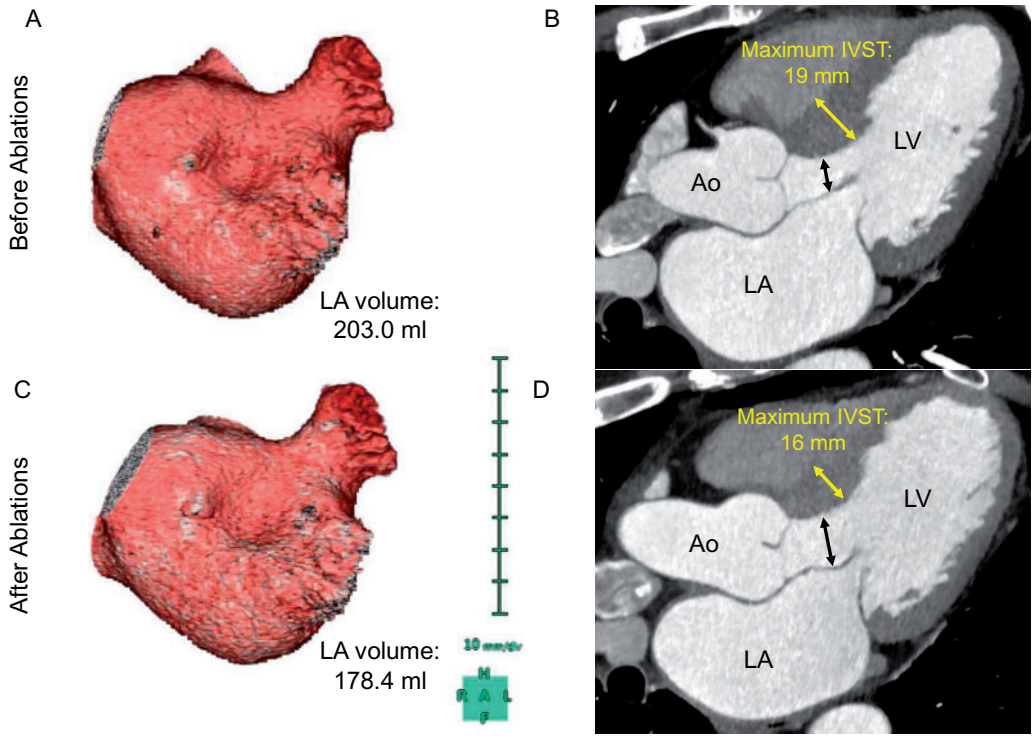
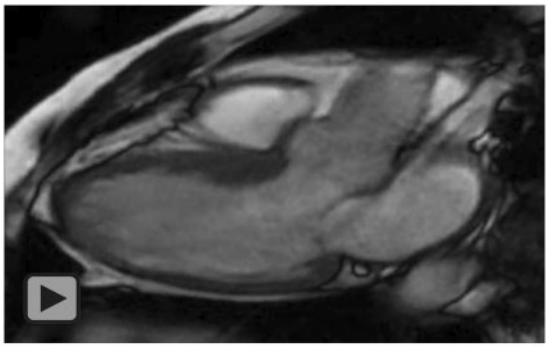


Figure 4 The multi-detector cardiac computed tomography before the atrial fibrillation ablation and 6 months after the alcohol septal ablation. (*A* and *B*) The volume rendering image (*A*) and the three-chamber view (*B*) of the left atrium before the atrial fibrillation ablation. The volume was 203 ml. (*C* and *D*) The volume rendering image (*C*) and the three-chamber view (*D*) of the left atrium 6 months after the alcohol septal ablation. The volume decreased to 178.4 mL; especially, the posterior side of the left atrium shrunk. The maximum thickness of left ventricular septum (yellow arrows) became thinner (19–16 mm), and the width of left ventricular outflow tract (black arrows) became wider, after the alcohol septal ablation. LA, left atrium; LV, left ventricle; Ao, ascending aorta; IVST, interventricular septum thickness.

symptoms on exertion and to also maintain the effect of AF ablation, through an improved LVOT obstruction and reduction of the left ventricular end-diastolic pressure.

For the ASA, a 6-French guide catheter was inserted into the left coronary artery ostium via the femoral artery. The first septal artery was tracked using a 0.014-inch hydrophilic wire (Fielder FC, Asahi Intec, Aichi, Japan) and was then occluded with an over-the-wire balloon (Emerge Over-the-wire 1.5 × 8 mm, Boston Scientific, Marlborough, MA, USA). After confirming the staining of the basal septum with contrast echocardiography, 2.5 mL of absolute ethanol was injected. Subsequently, the second septal artery was occluded using an over-the-wire balloon (Ryujin Plus Over-the-wire 1.25 × 10 mm, TERUMO, Tokyo, Japan) and 1.5 mL absolute ethanol was injected (*Figure 3A*). After ablation of two septal arteries, the peak-to-peak pressure gradient between the left ventricle and the ascending aorta decreased from 55 to 7 mmHg, during sinus rhythm (*Figure 3B*). Complete atrial-ventricular block never occurred both during and after the ASA (*Figure 3F*).

One week after the ASA, we confirmed the late gadolinium enhancement at the basal septum on CMR imaging (*Figure 3C*). The patient's heart failure symptoms improved to NYHA class I, and there were no reported symptoms of AF attack, though amiodarone use was continued. Six months after the ASA, the patient's serum NT-proBNP level decreased to 124 pg/mL and it remained between 100 and 200 pg/mL until one and a half years after the ASA (*Figure 3D*). On comparing his LA volume from the



Movie 2 Three-chamber cine images of cardiac magnetic resonance across the one cardiac cycle after the alcohol septal ablation.

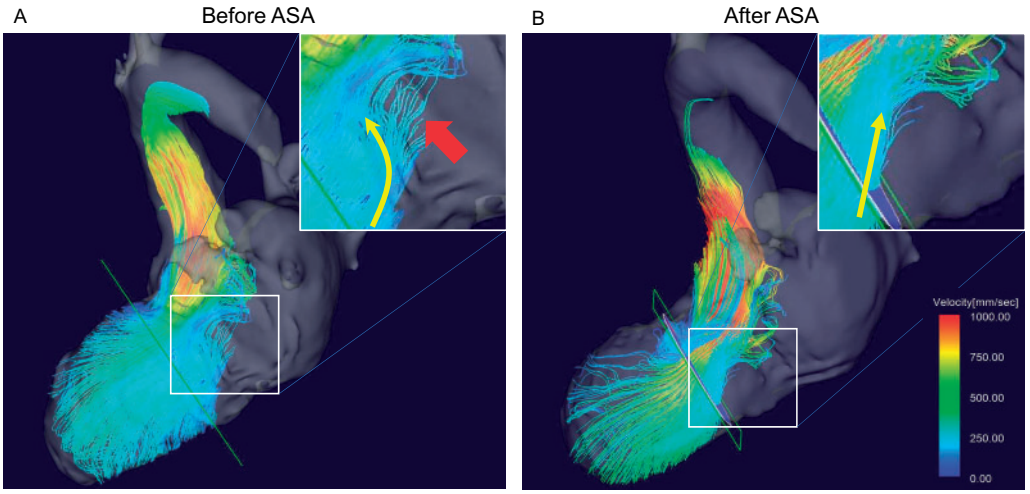
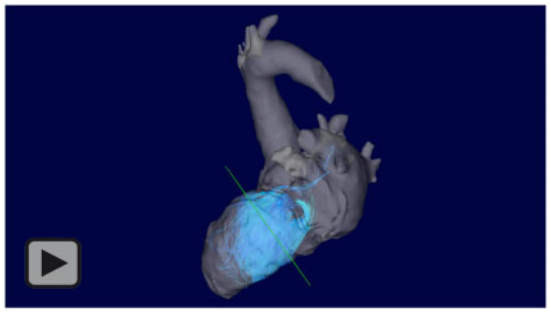


Figure 5 The streamline images, merged with 3D images, at peak systolic phase using 4D-flow cardiac magnetic resonance before and 6 months after the alcohol septal ablation. The velocity encoding was set at 5.0 m/s, and the analysis plane was set at the basal LV. The right upper panels in both A and B show the focused view of the posterior side of mitral annulus. (*A*) Before the alcohol septal ablation. The left-curved flow was formed below the posterior side of mitral annulus (yellow arrow), which was supposed to cause the drag force (red arrow) and systolic anterior motion. (*B*) After the alcohol septal ablation. The curved flow became straight (yellow arrow), resulting in the less drag force. The blood flow velocity in the ascending aorta increased (described with red line bundles), because of the release of the left ventricular outflow tract obstruction.



Movie 3 Streamline images of 4D-flow cardiac magnetic resonance across the one cardiac cycle before the alcohol septal ablation.

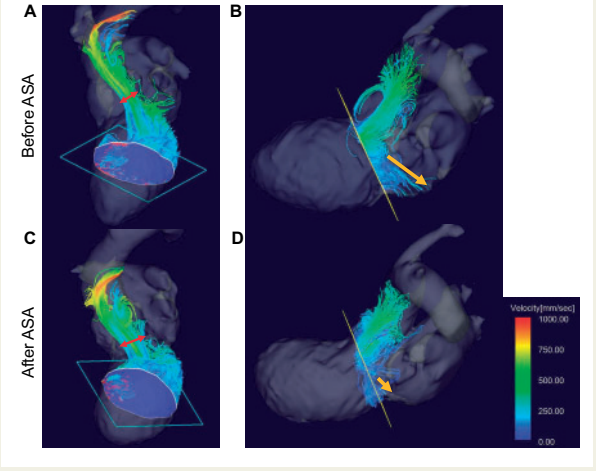


Figure 6 The streamline images of other angles, at peak systolic phase using 4D-flow cardiac magnetic resonance before and 6 months after the alcohol septal ablation. (*A* and *C*) The left anterior oblique view, before and after the alcohol septal ablation. The left ventricular outflow tract width (red arrows) became wider after the alcohol septal ablation. (*B* and *D*) The three-chamber view with the cross-section of mitral valve annulus. The mitral regurgitation to the posterior side of left atrium (orange arrows) decreased after the alcohol septal ablation.

first visit with that 6 months after the ASA, the diameter decreased from 56 to 45 mm on echocardiography, and the volume decreased from 203.0 to 178.4 mL on multi-detector computed tomography (*Figure 4A and C*). Multi-detector computed tomography also revealed thinning of the basal septum and an enlarged LVOT after the ASA (*Figure 4B and D*). The peak pressure gradient of the LVOT was maintained at 12 mmHg through echocardiography during sinus rhythm, and the SAM decreased from Grade 4 to Grade 2, even though the elongated mitral valve leaflets remained (*Figures 1G–J* and *2C and D*, and *Movie 2*). On 4D-flow CMR (GE Healthcare, Waukesha, WI, USA) performed 6 months after ASA, focused at the peak systolic phase, the left-curved streamlines from the posterior side of LVOT, lifting up the posterior mitral valve leaflet, were visualized before the ASA

(*Figure 5A* and *Movie 3*). The curved flow contributed to the drag force towards the mitral valve leaflets, resulting in the obvious SAM. The curved flow became straight after the ASA, resulting in a weakened SAM (*Figure 5B* and Supplementary material online, *Movie S4*). The enlargement of the LVOT and the decreased mitral regurgitation were also visualized on 4D-flow CMR (*Figure 6A–D*).3,5

Discussion

Atrial fibrillation is frequently concomitant with hypertrophic cardiomyopathy. The risk of thromboembolic events in AF patients with HCM is significantly higher than those without HCM.[3,5] Pulmonary vein isolation for AF patients with HCM is associated with a high percentage of AF recurrence because of the progressive diastolic dysfunction and LA enlargement.[6] Alcohol septal ablation, along with surgical myectomy, is considered as an effective septal reduction therapy that not only reduces LVOT obstruction but also improves left ventricular diastolic function and reduces the LA volume.[7] Notably, ASA followed by AF ablation might effectively prevent AF recurrence. In the present case, the significant SAM and SAM-induced mitral regurgitation due to the elongated mitral valve leaflets were attenuated by the ASA; consequently, the patient's AF ceased and his serum NT-proBNP level decreased.

The standard therapy indicated for drug-refractory HOCM with a mitral valve complex abnormality is surgical myectomy and mitral valve repair. Concomitant AF can be treated with the maze procedure during the operation. However, in the present patient, the drug-refractory HOCM with AF was successfully treated using transcatheter interventions. Moreover, the improvement in LVOT obstruction was visualized using 4D-flow CMR. Systolic anterior motion was mainly established by the lifting force, or 'drag force', of the posterior mitral valve leaflet. In HOCM patients with elongated mitral valve leaflets and a shorter distance between the coaptation point and septum, the mitral valve leaflets protrude into the LVOT, causing an isovolumic vortex under the mitral valve. The vortex flow impacts the mitral valve from below and lifts the leaflets up to the septum.[8] In the present case, the constricted LVOT flow from the posterior side of the mitral valve was obvious on 4D-flow CMR before the ASA and significantly improved after the ASA. We have already reported the utility of 4D-flow CMR for assessing the improvement of vortex flow in the ascending aorta after ASA in another HOCM case.[9] The results obtained in this case imply that 4D-flow CMR can be used for the assessment of SAM before and after septal reduction therapy in HOCM patients.

Conclusions

In the present case, drug-refractory HOCM concomitant with paroxysmal AF was successfully treated using transcatheter interventions. In addition, the detailed intra-ventricular haemodynamic assessment of HOCM patients was effectively performed using 4D-flow CMR.

Lead author biography

Keitaro Akita is an interventional cardiologist, who specializing in the interventions for coronary artery diseases and structural heart diseases. He received MD degree from Keio University, Tokyo, Japan in 2010, and received PhD degree form Keio University, Tokyo, Japan in 2018. His research interests are mainly focused on hypertrophic cardiomyopathy.

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 patient in line with COPE guidance.

Conflict of interest: none declared.

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